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TOPOGRAPHIC ATLAS

OF THE

UNITED STATES

PHYSICAL GEOGRAPHY

OF THE

TEXAS REGION

BY

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CONTENTS

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CONTENTS OF DESCRIPTIVE TEXT.

PHYSICAL GEOGRAPHY OF THE TEXAS REGION.

INTRODUCTION.

In this paper the author has endeavored to present a scientific outline of the physiographic features of the Texas region, as shown on a new map herewith (Sheet XI), and to define its salient generic natural subdivisions, as a basis for more detailed discussion and differentiation of the various phenomena in the future. The limits and plan of the paper forbid extended discussion or description of specific local features.

Data on which map is based.—The map, on a scale of 25 miles to the inch, is intended to show, so far as can be shown on that scale, all that is known concerning the physical geography of the region. Many of the minor details of culture have been intentionally omitted, in order that the physiographic features may stand forth more clearly; only the political boundaries, the railroads, and the names of States, counties, and county seats are given, except a few important towns here and there, which are conspicuous landmarks. In compiling the map the author has drawn, for data, from every possible source, including all known surveys and reconnaissances. The data may be classified under six distinct heads:

1. Detailed topographic surveys by the United States Geological Survey and the special land survey of the Indian Territory.
2. The survey of the coast of the Gulf of Mexico and triangulation of the lower Rio Grande border by the United States Coast and Geodetic Survey.
3. The surveys of the various boundary commissions.
4. The drainage of the eastern half of Texas as given on Pressler and Langermann's map of Texas, compiled from the Texas land surveys, 1877, and the United States Land Office maps of Indian Territory and New Mexico.
5. Reconnaissance surveys made by various United States exploring and railway expeditions.
6. The individual reconnaissances and observations of the writer.

Future work will no doubt supply details for many of the unsurveyed parts of the region, especially those embracing the unsurveyed portion of eastern New Mexico and the portion of Texas included in the great bend of the Rio Grande. The author feels confident, however, that the map presents as close an approximation to a correct representation of the geography of the region as it is possible to attain with our present incomplete knowledge.

The portions of the map covered by the above data are shown in fig. 12, Sheet I, Special Illustrations.

GREATER TEXAS REGION.

The American pioneers of the original Republic of Texas defined its limits as that country lying between the Rio Grande and the Arkansas to their headwaters, extending east to the one hundredth meridian, as laid down on Mellish's map, north of Red River, and east to the Sabine south of the latter stream. The boundaries of the Republic of Texas as specified in an act of the Texas Congress approved by President Houston December 19, 1836, were as follows:

> Beginning at the mouth of the Sabine River and running west along the Gulf of Mexico, three leagues from land, to the mouth of the Rio Grande, thence up the principal stream of said river to its source, thence due north to the forty-second degree of north latitude, thence along the boundary line as defined in the treaty between the United States and Spain, to the beginning.

The northern and eastern boundaries of the Republic of Texas above mentioned, as defined in the treaty between the United States and Spain, were as follows:

> The boundary line between the two countries, west of the Mississippi, shall begin on the Gulph of Mexico, at the mouth of the river Sabine, in the sea, continuing north, along the western bank of that river, to the thirty-second degree of latitude; thence by a line due north to the degree of latitude where it strikes the Rio Roxo of Nachitoches or Red River; then following the course of the Rio Roxo to the degree of longitude 100° west from London, or about 23° west of Washington; then crossing the said Rio Roxo and running thence, by a line due north, to the River Arkansas; thence, following the course of the southern bank of the Arkansas, to its source in latitude 42° north.

There was then little accurate knowledge of the sources of the rivers mentioned in these treaties or of the geography of the country with which they dealt. The boundaries of the Republic of Texas included a large section of our country—Texas, southern Kansas, Oklahoma, eastern New Mexico, and a portion of Indian Territory—which, by reason of its natural relations, may be appropriately termed the Greater Texas region. The political boundaries have since been restricted to the present limits of the State, and it is this restricted area which will chiefly be considered in this paper, although it will often be necessary to extend descriptions of natural features into adjacent and related regions.

The Greater Texas region includes practically all the country east of the Rio Grande south of the northern boundary of New Mexico. The great Mesa de Maya, which extends eastward along the Colorado–New Mexico boundary from the one hundred and fifth meridian near Trinidad nearly to the northwest corner of Texas, forms a natural physiographic barrier dividing the western part of the Great Plains into northern and southern portions. From the eastern limit of this mesa eastward the Purgatory and the Arkansas below the mouth of the Purgatory make the northern boundary as far east as the one hundredth meridian. Thence the northern boundary is made by the Breaks of the Plains, running eastward and northeastward in southern and eastern Kansas, until they intercept the southern border of the glaciated plains in northeast Kansas.

The eastern border of the Greater Texas region is irregular and may be considered as the western border of the Ozark Plateau of eastern Missouri and northeastern Indian Territory as far south as Arkansas River, where the Ouachita Mountains are encountered. The latter form a long tongue-like projection which stretches westward into the Greater Texas region. South of the Ouachita Mountains there are no physiographic features to mark the eastern border of the area, the Coastal Plain continuing east indefinitely. For the line of limitation we assume the western boundaries of Arkansas and Louisiana. On the south the Gulf of Mexico and the Rio Grande are the natural boundaries.

The Greater Texas region thus defined is not a physical unit, but rather an area which includes a peculiar group of physiographic units, composed of mountains and plains, belonging to the four greater natural provinces of the United States, to wit: the Cordilleran region, the Great Plains region, the Appalachian region, and the Atlantic Coastal Plain. The extensions of these features into the State present local modifications. There are also extensive stretches of country in the central portion of the State which have no counterpart elsewhere. Before the individual physiographic features of the Greater Texas region are described the area, relations, and subdivisions of the State will be noticed.

THE STATE OF TEXAS.

AREA AND RELATIONS.

The area of the State of Texas is 265,780 square miles, or about one-twelfth that of the entire United States. Its magnitude will be better appreciated when it is remembered that to the combined area of the New England States, New York, New Jersey, Pennsylvania, Delaware, Maryland, and the District of Columbia, the areas of Ohio and Kentucky must be added to equal it. Its extent is about that of France. Its length and breadth are nearly the same. The former is 760 miles, and the latter, along the thirty-second parallel, is about 740 miles. By rail these distances are 900 miles, or the same as from New York to Savannah, Atlanta, Chattanooga, Evansville (Indiana), Chicago, or Labrador. Its length is one-half that of our country from north to south. Its width is more than one-half the southern border of the United States between the Atlantic and the Pacific. This width is equal to one-third the distance across the widest portion of the country, from Cape Hatteras to Cape Mendocino.

In respect to location and natural conditions Texas does not fit exactly into any one of the ordinary classifications of States. It is southern—Florida excepted, the most southern of all the States in geographic position. It is central, for it is one of the great tier that exactly forms the central strip of the Union. It is a Gulf State, and has one-fourth the shore line of the Gulf of Mexico. It is a western State, large areas of both the Great Plains and the Cordilleran regions being included in it, while its far western corner is nearer the Pacific than the Atlantic and has the climatic features of the former rather than of the latter. Not only do its parts present the geographic features of the larger divisions of the United States already mentioned, but there are areas typical of the adjacent Republic of Mexico, such as the northern end of the Tierra Caliente at the mouth of the Rio Grande. Hence it may be said that Texas is both southern, central, and western in relative position and interests.

SUBDIVISIONS OF THE STATE.

Neither the State of Texas nor the adjacent territories within the Greater Texas region have well-defined or officially recognized subdivisions. In Texas vague subdivisional terms have grown into popular use, but these have not been recorded or defined. Personal observation of this local usage shows that it includes two classes of terms: first, terms of direction, vaguely applied without definite reference to natural subdivisions; second, names based on specific natural features and applied to local districts colloquially called "countries."

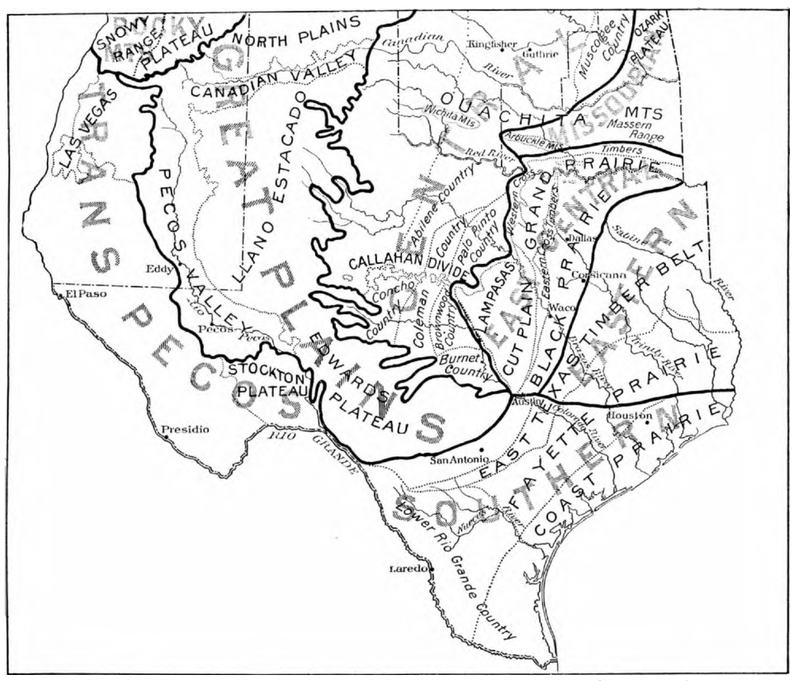

Fig. 1.—Provinces and minor subdivisions of the Greater Texas region.

ARTIFICIAL SUBDIVISIONS.

The directional names in common use in Texas are as follows: East Texas, Southwest Texas, Central Texas, Northwest Texas, North Texas, and West Texas. The bounds of the areas which these terms are intended to designate have never been defined, and it is doubtful whether they are well formulated in the public mind. They were not originally used with reference to the geographic center of the State, but were and still are employed with reference to the early American centers of population in the extreme eastern part. Thus all the areas to which these names are applied lie east of the central meridian of the State. Southwest Texas, for instance, according to this older nomenclature, embraces the country between the Balcones scarp line, the Rio Grande, and the coast. This region, relative to the geographic center of the State, is really southern Texas, as it will be called in this folio. Central Texas was the region traversed by the Houston and Texas Central Railway, and included a country (the east half of the East-Central Province of nomenclature) more than 100 miles east of the true Central Province as defined in this paper. North Texas was the tier of black-land counties adjacent to Red River, and included only the eastern third of the northern border. Northwest Texas was almost the exact geographic center of the State. The term West Texas was applied to the region immediately beyond the westwardly migrating line of frontier settlement.

NATURAL SUBDIVISIONS.

No set of directional terms coincides exactly with the natural subdivisions of the State; nevertheless, such terms are convenient and often unavoidable in description. The use made of them in this folio, however, is quite different from that noticed in the last paragraph, and results from a new classification of the region into provinces, based on physical characters and relations.

The parts of the Greater Texas region which, by reason of natural features—characteristics of soil, climate, geologic structure, drainage, underground water conditions, and environment for human culture—constitute geographic units for discussion, or provinces, are six in number (see fig. 1). These provinces may be briefly outlined as follows:

1. *The Eastern Province.*—This consists of the northern half of the Texas Coastal Plain, and includes the forest country east of the Black Prairie and north of the thirtieth parallel, which corresponds approximately to the latitude of Austin. It represents the continuation into Texas from Arkansas and Louisiana of the Atlantic timber belt of the interior portion of the southern Coastal Plain. In Texas it embraces 33,000 square miles.

2. *The Southern Province.*—This is the southern half of the Coastal Plain in Texas and the modified southern extension of the Eastern Province. It includes the area between the thirtieth parallel on the north, the Balcones scarp line on the west, and the Rio Grande on the south as far west as Del Rio. It contains a diverse group of countries, such as the Coast Prairie, the Fayette Prairie, the Carrizo country (an attenuated southwestern extension of the Atlantic timber belt), the Comal country (the southern continuation of the Black Prairie), and the Rio Grande embayment. Its area aggregates 52,000 square miles.

3. *The East-Central Province.*—This includes the portion of Texas north of the Colorado between the Eastern Province and the Central Province proper, and the portion of southern Indian Territory south of the Ouachita Mountains and east of the ninety-seventh meridian. It includes the Black and Grand prairies and the two belts of timber known as the Western and Eastern Cross Timbers. Its area is about 31,000 square miles.

4. *The Central Province.*—This is a vast area of diversified prairie plains in southern Kansas, Oklahoma, Indian Territory, and Texas, lying between the Plateau of the Plains and the western border of the Ozark Plateau and the East-Central Province. It is the Central Denuded region of the writer's previous papers, and consists of a number of diverse prairie features occurring in more or less regular north-south belts succeeding one another to the west, including those established upon the Red Beds, the Carboniferous, and the older Paleozoic rocks, each of which will be described under its appropriate head. The area of its southern portion which lies in Texas is 37,000 square miles.

5. *The Great Plains Province.*—This includes the Great Plains proper, which extend eastward from the Rocky Mountain front to the prairie plains of the Central Province and southward to the Southern Province.

5a. *The Plateau Subprovince of the Great Plains.*—This is the modified southern extension of the Great Plains region of the United States. In Texas it is an extensive oblong plateau south of Canadian River, comprising the Llano Estacado and the Edwards Plateau—60,000 square miles. The Stockton Plateau, between the Pecos and the

Rio Grande and the eastern front of the mountains, which may be included in the Plateau Province, has an area of about 15,000 square miles.

6. *The Trans-Pecos Province.*—This represents the continuation of the eastern ranges, plateau plains, and interior basins of the great Cordilleran region of western United States west of the Pecos and southward from northern New Mexico, through Texas, into the eastern Sierra Madre of Mexico. The portion in Texas embraces 35,000 square miles.

Provisional subdivisions into "countries."—In Texas the name "country" is used locally for more limited districts (subdivisions of the provinces) which have some peculiar or specific natural unity of soil, flora, or topography. Thus we have the Coast and the Pine Woods countries for certain subdivisions of the Eastern Province of the State; the Abilene, Wichita, Brownwood, San Angelo, San Saba, and Llano countries for subdivisions of the Central Province; the Uvalde, Laredo, Carrizo, and Brownsville countries for subdivisions of the Southern Province; the Plains, Panhandle, and Pecos Valley countries for subdivisions of the Great Plains Province; and the Big Bend, El Paso, Marathon, Fort Davis, and other names for the "countries" of the Trans-Pecos Province. No definite bounds of these can be fixed without good surveys and maps, which have not been completed, and hence exact definitions or descriptions of the countries are not attempted in this paper. Each forms a unit worthy of consideration in a special paper.

THE RELIEF.

The relief features of the Greater Texas region range from vast stretches of apparently level country, like the Llano Estacado and Coast Prairie, presenting no visible breaks in their plainlike extent, to the rugged mountains of the Trans-Pecos Province, marked in places along the Rio Grande by abrupt canyons and declivities.

This relief, as a whole, may be classified as that of the mountains and that of the plains. The altitudes of the region vary from sea level to 13,000 feet. (See fig. 13, Sheet I, Special Illustrations; also Sheet XI, Map of Texas, etc.)

Broader features of the relief.—In a broad sense the Greater Texas region consists of a vast and diversified plain bordered on the west and north by mountains. That portion between the eastern front of the Cordilleras and the sea may be primarily conceived as an elongated plain. This plain inclines gently from the Cordilleras toward the sea. The inclination from the foot of the Cordilleras to the Gulf is generally in an easterly direction, but there are slight variations of direction. This general inclination may be specifically called the Regional Coastward Slope, and its variation in gradient and direction, as will be explained later, has an important relation to the physiographic history. Except in the extreme northwestern corner of Texas, where the Great Plains continue north unbroken, and on the east, where the coast plains border the sea or continue into Louisiana, the Regional Coastward Slope is terminated by either the Cordilleran or the Ouachitan mountain system, which extend at approximately right angles to each other, diverging so as to inclose the plain in a triangle having its wider base toward the sea. The slope of the plain is rudely comparable to a wide, low stairway, leading from the sea to the Cordilleras, in which the various subdivisions of the plain represent the treads, local escarpments the rises, and the limiting mountains the balustrades. This analogy can not be carried far, for great irregularities occur in the width and tread of the steps, and the wear and tear of time has scarred and disfigured their relief, etched valleys where the drainage depressions have crossed the plains, and lowered the mountain walls. Some escarpment steps in exceptional instances face westward, or upstairs, while other subdivisions of the plain succeed one another without any well-defined feature of relief. Furthermore, the structure of the inclosing mountain systems is of two entirely different types and periods of architecture. The formations which underlie some of the plains are crumpled up in the Cordilleras and are deposited against the Ouachitas. Hence, parts of the plains are older than the Rocky Mountains and younger than the Ouachita uplifts.

Specific features of the relief.—The chief specific features of the relief, each of which will be subsequently described, may be enumerated as follows:

Mountains:
- Ouachita Mountains.
- Trans-Pecos Mountains.

Plains:
- Plains of the Regional Coastward Slope.
  - The Great Plains.
    - North Plains.
    - Llano Estacado.
    - Edwards Plateau.
    - Stockton Plateau.
      - Pecos Valley.
      - Canadian Valley.
  - Prairie plains.
    - Muscogee Prairies.
    - Oklahoma Plains.
    - Grand Prairie.
      - Western Cross Timbers.
    - Black Prairie.
      - Eastern Cross Timbers.
  - Coast plains.
    - East Texas timber belt.
    - Coast Prairie.
    - Rio Grande embayment.
- Plains of the Trans-Pecos Province.
  - Plateau plains.
  - Bolson plains.

Each of the diverse features alluded to has an area equivalent to that of an average State of the Union; each is distinguished from the others by different types of soil, rocks, drainage, and agricultural and industrial possibilities.

Before describing these features in detail it is essential to state briefly the salient geologic conditions upon which their existence is dependent.

RELATION OF RELIEF TO FORMATION.

Nowhere is there a more intimate relation between geologic formation and physiography than in the Texas region. Nearly all topographic conditions which influence human environment, except climate, depend on the composition and arrangement of the various rock sheets. Each formation has peculiarities of stratification, consolidation, cohesion, friability, and porosity which, when the formation is acted upon by climatic factors, result in various relief forms.

INFLUENCE OF TEXTURE AND STRUCTURE ON RELIEF.

The induration or hardness of the rock sheet is the chief factor influencing the character of the relief. All hills, scarps, plateaus, mountains, and other relief features of Texas are manifestations of the survival of the hardest in the denuding processes of land degradation; correspondingly, the minute configuration of the stream valleys, valley plains, escarpments, and many of the level prairies bordered or surrounded by scarps also depend upon the relative hardness of the rocks.

The inclination of the rock sheets is an important factor in producing relief. Where these are horizontal or but gently inclined the tendency is toward plane surfaces with vertical cliffs bordering the drainage grooves; where steeply inclined, ragged mountainous forms are the resultant relief.

Consolidation, friability, cohesion, solubility, and porosity modify the relief in various ways. Loose sands are heaped by the wind into low hills or dunes; unconsolidated clays weather into rounded hills and flat surfaces; soluble rocks produce sink holes and other irregular surfaces, with caverns and bluffs, and the degree of porosity facilitates or retards decay.

Especially in the non-mountainous part of Texas, each formation produces a characteristic relief and weathers into its own distinctive type of soil, the color of which—white, red, black, brown, or yellow—gives a peculiar tone to the resulting landscape, accompanied by floral individualities resulting from the texture and composition of the soil. Sometimes a simple group of strata, like the Plains formations, which extend over 40,000 square miles, produces an extensive uniform region, with less differentiation in physical features than is found elsewhere within the area of an ordinary township.

In general, as has already been explained, the relief of the Greater Texas region resolves itself into two broad types: (1) true mountainous areas (the Trans-Pecos and Ouachitan), in which the rock sheets are comparatively more tilted or otherwise deformed, and (2) a greater plains region, that of the Regional Coastward Slope, in which the rock sheets, largely the same as those which make the mountains, are but slightly inclined and form vast extents of sublevel surfaces rather than eminences. The area of Oklahoma, Indian Territory, and southern Kansas, north of the Ouachita Mountains, is included under this general head, though its slope is not strictly coastward, but toward the Mississippi.

KINDS OF RELIEF-MAKING ROCKS.

Most of the surface of Texas is formed of sedimentary rocks, igneous formations covering less area. There are also extensive formations composed of wind-blown débris, chemical precipitates, and upland drift.

The sedimentary rocks, superimposed one above another in more or less orderly succession, are of two general classes: (1) marine formations, originally laid down upon the marginal bottoms of the sea; (2) surficial formations, deposited upon the slopes of the land or at local deposition levels, such as lakes, rivers, or other bodies of water which occur within the land areas.

MARINE SEDIMENTARY ROCKS.

The sedimentary rocks laid down on the sea bottom are of all ages from Cambrian to Recent, with the possible exception of the Devonian.

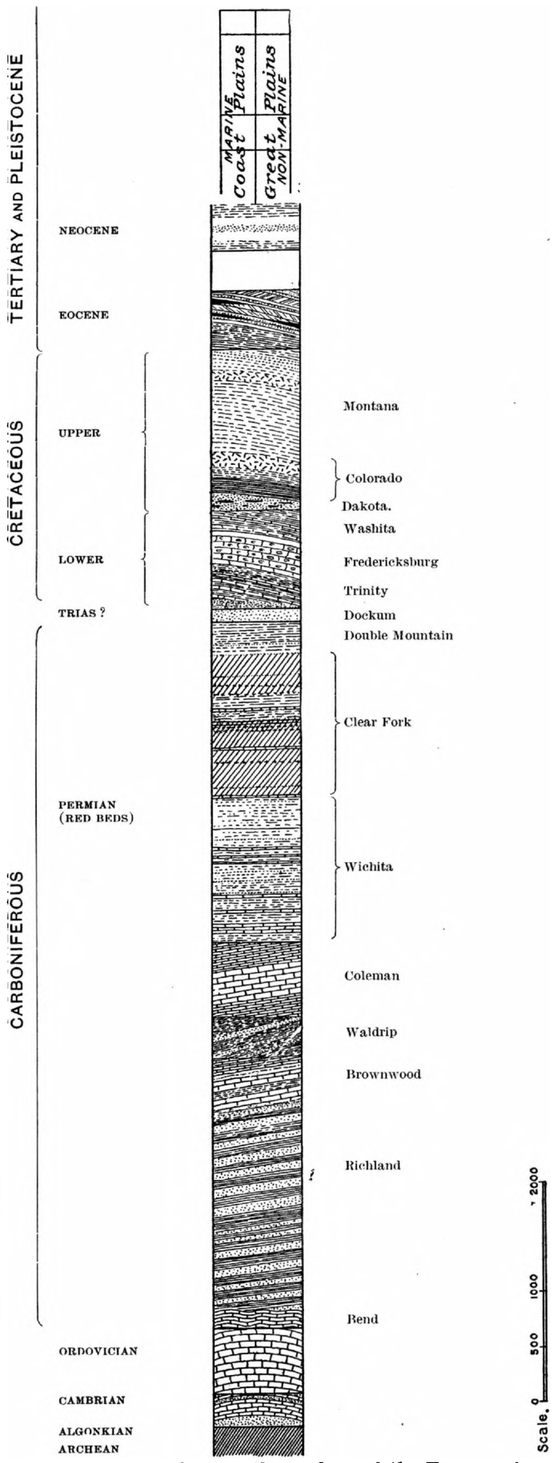

Fig. 2.—Section showing the geology of the Texas region.

They aggregate about 25,000 feet in thickness, as shown in the accompanying systematic table and vertical section, fig. 2. (See also fig. 14, Sheet I, Special Illustrations.) These rocks occur as strata of differing hardness, tilted at steep angles in the mountainous areas, and nearly horizontal in the plains region. They are of two general classes, differing in occurrence and relative importance, viz:

1. An older or fundamental series of pre-Cretaceous formations. The structural arrangement of these formations, in anticlines and synclines, is discordant with that of the later formations of the Coastward Slope. The series represents the remains of an ancient topography which was base-leveled during Jurassic and Cretaceous time, prior to the invasion of the Cretaceous seas, which completely buried it with later sediments. These older rocks, except in the mountains, are now seen only where areas of the later strata have been worn away. In the structure of this group is written an interesting pre-Cretaceous history, involving the growth and decay of land areas quite different in detail from those of the present time.

2. Formations of the Coastward Slope from Cretaceous to Recent age. Most of these rocks were once marginal deposits of the Gulf of Mexico, laid down when it extended much farther inland than it does to-day; and they were elevated as the Gulf receded from the Rocky Mountain front to its present position. All these strata now incline toward the sea. In some instances the inclination coincides with the surface slope, while in others it is slightly greater.

Relief expression of the older or Paleozoic sedimentaries.—Classified according to geographic importance the older rocks may be divided into two groups—the earlier and the later Paleozoic. The first includes the Algonkian and Cambro-Ordovician; the second, the Carboniferous and Permian. They may be divided into four greater lithologic subdivisions—the pre-Cambrian, the Cambro-Ordovician, the Carboniferous, and the Permo-Triassic Red Beds. Of these the first two are usually more or less associated in geographic occurrence in limited areas, and by reason of their hardness produce allied features of topographic relief. The third and fourth, forming the surfaces of large areas, have each individual features.

Pre-Cambrian and older Paleozoic rocks are the foundation upon which all the other rocks were laid down, and are still in the main covered by them. Their outcrops are exceptional and restricted in area; they occur in small districts in the Wichita and Arbuckle ranges of the Ouachita Mountain system, in some of the Trans-Pecos Mountains, especially the district between the thirty-first and thirty-second parallels, and in a limited territory in the southern end of the Central Province known as the Burnet country.

The pre-Cambrian rocks are mostly schists and granites; the former are greatly disturbed and weather into angular vertical knife-edges of projecting hard strata or low mammillary hills. The Cambro-Silurian rocks are indurated sandstones and limestones which weather into rounded hills with steep slopes. They usually occur in geographic association with the pre-Cambrian rocks.

The Carboniferous rocks are the chief formations of the eastern or Massern Ranges of the Ouachita Mountains, the eastern border of the Central Province in Indian Territory and Texas, and the Diablo, Guadalupe, and Caballos mountains of Trans-Pecos Texas. The Permian, or Red Beds, prevail in the greater part of the Central Province and in the Pecos and Canadian valleys. Both Carboniferous and Permian formations occupy an old synclinal trough between the Grand Prairie and Ozark Plateau on the east and the Cordilleras on the west, which was buried by the Cretaceous formations. The Carboniferous and Permian rocks produce somewhat allied but different topographic forms. The Carboniferous, largely made up of soft, impure shales alternating with harder, coarse, brown sandstones and conglomerates, produces ridgelike mountains and a broken belt of country along the eastern margin of the Central Province, composed of rough-scarped and flat-topped sandstone plains and hills of circumdenudation, surrounded by and overlooking wide clay valleys called "flats." The Permian Red Beds aggregate some 7000 feet in thickness and consist largely of unindurated arenaceous clays, with only a few hard strata. They weather into extensive flat regions with occasional scarp lines attended by "bad-land" slopes. They occupy the western and greater part of the Central Province and extend beneath the Plateau of the Plains and outcrop in Pecos Valley against the eastern front of the Cordilleras.

Relief expression of the Mesozoic and later rocks.—The existence of the early Mesozoic (Triassic) is doubtful, although possible. Rocks referred to this period overlie the Permian along the western part of the Central Province and appear in small areas around the border of the Plateau of the Plains, but are of no topographic significance. Jurassic limestone strata of the Mexican type have been found in only a limited area in the barren ranges west of the Cordilleran front and are not known on the Atlantic slope or the eastern Front Ranges.

The later group of formations, those of the Coastward Slope, consists of sheets of sea-made sediments, from Cretaceous to Pleistocene age, inclusive, and of aggradational deposits of upland wash and stream and lacustral alluvium of Tertiary and later age, all of which, except the Lower Cretaceous, are mostly unconsolidated terranes of clay, sand, marl, and loam. Of this later group, the marine Cretaceous, Tertiary, and Pleistocene rocks are the chief formations, especially east and south of the Central Province. They were unconformably deposited across the upturned edges of the older formations above described. They may be subdivided into two general series, producing two broad variations of low relief: (1) the older Cretaceous formations, and (2) the newer Cretaceous, Tertiary, and Pleistocene formations. These rocks occur in belts, each underlying a broad strip of country.

The Cretaceous rocks are divisible into an older or lower and a newer or upper series. They occur in the Trans-Pecos Mountains and in the Coastward Slope plain. The older formations consist of hard limestones alternating with clays, and are underlain by sands; they produce dip plains, cut plains, and low scarps. The Upper Cretaceous strata consist largely of unindurated clay marls, with a few indurated scarp-making strata, all underlain by sands and weathering into low, undulating areas.

Of all the Texas formations influencing the relief the Upper and Lower Cretaceous rocks have the largest areal development. They extend from southern Indian Territory, where their horizontal strata abruptly end against the upturned Paleozoic strata of the Ouachita Mountains, southwest toward the Trans-Pecos and Mexican cordilleras, which are largely composed of their crumpled sheets. The upper and younger Cretaceous rocks, being softer and yielding more readily to disintegration, usually underlie level plains. The lower and older Cretaceous formations, composed of hard, resisting limestones, weather into sharp relief features — scarps, plateaus, and mountains — and, with the exception of the high volcanoes of southern Mexico, compose most of the high relief of Texas and Mexico. They are also cavernous (see fig. 30, Sheet III, Special Illustrations). The newer Cretaceous rocks form the Black Prairie of the East-Central Province and the interior portion of the Southern Province. The older Cretaceous rocks form the southern part of the Plateau Province, the Callahan Divide, the Lampasas Cut Plain, and many of the Trans-Pecos Mountains.

The marine Tertiary and Pleistocene sediments are found only to the coastward of the later Cretaceous formations in the Eastern and Southern provinces, making, with portions of the later Cretaceous, the formations of the Coastal Plain. The Eocene Tertiary strata are mostly unconsolidated alterations of sand and clay, with exceptional local indurations of ferruginous sandstone. The later marine sedimentaries of the Coast Prairie district (Miocene to Recent) have not been classified by age, but collectively they make a great thickness of unconsolidated sands and clays of late Tertiary and Pleistocene age. According to well borings at Galveston, they are over 3000 feet thick. They produce a remarkably level topography — apparently a new plain lately reclaimed from the sea.

SEDIMENTARY ROCKS OF OTHER THAN MARINE FORMATION.

The non-marine deposits of Texas are lacustral deposits, sheets of upland gravel and alluvial wash, "tepetate,"[1] and wind-made formations, all of which were laid down at local deposition levels. Of these formations the alluvium is found throughout the whole region, in the valleys of all streamways, and even over the uplands of much of the Southern and East-Central provinces. The lacustral deposits are found in valleys of the Cordilleran region, partially filling the desert basins. The upland formations (the "wash"[2]) are flood sheets of gravel, sand, and marl, sometimes consolidated in the calcareous matrix known as "tepetate." They cap the Llano Estacado and occur along the interior margin of the Southern Province at the foot of the Balcones escarpment, consisting of the worked-over talus of the mountains and the débris of the Edwards Cut Plain. These deposits, initiated in Tertiary time, are in constant process of formation. The wash and tepetate occur on most of the slopes of the semi-arid and arid regions, where streams evaporate and sink into the plains, in the wind-made formations on the Llano Estacado, and in the valleys of the Great Plains and Central provinces.

RELIEF FEATURES OF THE IGNEOUS ROCKS.

The igneous rocks, in respect of occurrence, are of three classes: (1) the older granites accompanying the pre-Cambrian or fundamental rocks, upon which the whole superstructure of fossiliferous rocks may have been laid down; (2) intrusive rocks, pushed up through and between the other rock sheets and necessarily of later age than the rocks which they intrude; and (3) extrusive rocks, which have flowed or fallen over the surface. The oldest igneous rocks of Texas, included in class 1, and herein called fundamental, strictly speaking are not such, inasmuch as some of them at least are intruded into schists which are the lowest of this portion of the earth's crust visible to our inspection.

The old granites outcrop in the Llano country of the Central Province, in the Franklin, Hueco, and Cornudas mountains of the Trans-Pecos Province, and in the central and western half of the Ouachita Mountains. They are not of extensive topographic importance.

The intrusive rocks occur extensively in the Trans-Pecos Province, and exceptionally along the interior border of the Rio Grande embayment.

Extruded rocks of Cretaceous and Tertiary age occur chiefly in the Cordilleran region, as necks, dikes, flows, and cones. Volcanic necks of rhyolite form in part the extensive mountain groups known as the Chisos, Corazones, and Davis. Extensive flows of basalt and rhyolite make the indurated cap rocks of such features as the scarped cut plains of the Davis Mountains and the Mesa de Maya. Extrusive sheets of lava known as "malpais" are also found in the floor of the Hueco Basin of the Trans-Pecos Province. Volcanic craters, or cinder cones, which are exceptional features, occur in northeast New Mexico east of the Rocky Mountain front and in central New Mexico.

The marine sedimentary rocks of the Cordilleran region are of various ages prior to the Tertiary, representing in part the survival of structural features of pre-Cretaceous time, mostly buried by later deposits of Cretaceous rocks.

The Ouachita group is made up of the same Paleozoic beds that form the foundations of the non-mountainous regions, where they are buried beneath the later rock sheets. In the mountains the Algonkian, Cambro-Silurian, and Carboniferous rocks are the survivals of ancient land masses that were not base-leveled in pre-Cretaceous time. Their arrangement in long anticlinal folds more or less influences the present relief, and, assisted by erosion, produces a type of configuration quite different from that of the mountains of the Cordilleras.

The mountains of the Trans-Pecos Province are composed not only of the older sedimentary rocks found in the Ouachita uplift and the floor of the Coastward Slope plain, but also of the Cretaceous rocks which make much of the surface of the latter region. Here they are folded and tilted into mountain structure, while sheets and necks of hard eruptive rock, produced in Mesozoic and Cenozoic time, furnish further relief-making elements. The marine Tertiary and Pleistocene formations of the Coastal Plain are missing, but in the flats and basins between the mountains are extensive unconsolidated non-marine deposits, probably of synchronous age.

THE MOUNTAINS.

Within the Greater Texas region are two mountain systems — the Ouachita system of Arkansas and Indian Territory, and the Trans-Pecos Mountains. These systems are of different structural types, ages, and configuration, and trend approximately at right angles to each other. The Ouachita system is Appalachian in structure and general resemblance, and is thereby related to the eastern half of the United States; the Trans-Pecos Mountains, on the other hand, are a part of the great Cordilleran system which dominates the western half of the continent between the Great Plains and the Pacific.

OUACHITA SYSTEM.

This system extends east and west between the ninety-third and one hundredth meridians, from the Mississippi embayment of the Coastal Plain to the plateau of the Great Plains, through western Arkansas, Indian Territory, and Oklahoma. The system as a whole is a narrow line of old mountains, whose summit nowhere exceeds 3000 feet. It is composed of three principal groups, of different types of relief and rock composition; these are the Massern Ranges on the east, the Arbuckle Hills in the center, and the Wichita Mountains on the west.

The Massern Ranges were so named by Thomas Nuttall on a map accompanying his book entitled A Journey of Travels into the Arkansas Territory during the Year 1819: Philadelphia, 1820. These consist of elongated ridges of vertically folded clays and sandstones with some limestone, mostly of Carboniferous age. They extend east and west to longitude 95° 30′, where they change to a southerly direction, ending in a manner as yet not satisfactorily explained, at the northern edge of the Grand Prairie and against the eastern end of the Arbuckle Hills. The southward continuation of these folds was planed off and buried beneath the Cretaceous rocks of the Grand Prairie of Texas (see fig. 45, Sheet VI, Types of Mountains).

The Arbuckle Ranges extend from the ninety-sixth to the ninety-eighth meridian, in a series of low limestone ridges and granitic hills which strike in a direction north of west. These are old mountains composed of vertically folded limestone strata with a granitic base, exposed toward their eastern end, in the vicinity of Tishomingo. They have been so degraded that they have lost that magnitude which is usually associated with mountains.

The Wichita Range is the western end of the Ouachita system, and forms a rugged sierra between

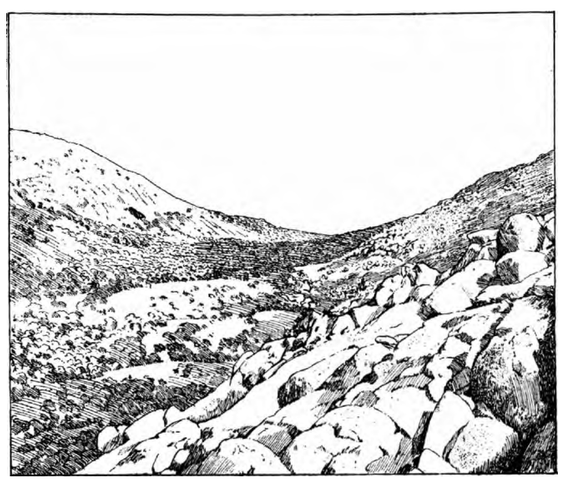

Fig. 3.—Granite ridges of the Wichita Range.

longitudes 98° 30′ and 100°. The highest peak, Mount Sheridan, rises 2500 feet — about 1300 feet above the surrounding plains, which are composed of old granitic and volcanic rock projecting through flanks of Silurian limestone (see fig. 3).

The mountains of this system in general are old, and represent the remnants of once more lofty and extensive ranges which have undergone degradation since early Mesozoic time.

MOUNTAINS OF THE TRANS-PECOS PROVINCE.

The Trans-Pecos Province is a peculiar combination of mountains and stretches of plateau plain and bolsons, surrounding, bordering, and lying between mountain ranges. The plains will be discussed later under a separate head.

GENERAL FEATURES.

The Trans-Pecos Mountains of Texas and New Mexico lie between the Pecos and the Rio Grande south of latitude 35° 30′. They represent the eastern Front Ranges of that portion of the North American Cordilleras between the southern end of the Rocky Mountains, in northern New Mexico, and the northern end of the eastern sierras of Mexico. These mountains are called by some the Continental Divide, but erroneously, for the Cordilleran region has no single dividing ridge in this latitude, but is a canoe-shaped area, bordered toward the Pacific and Great Plains by broken crests between which are basin plains and low mountain ridges (see figs. 25 and 28, Sheet III, Special Illustrations).

By origin these mountains are of three distinct types, as follows:

1. True mountains of deformation, composed of structural folds or tilted fault blocks of sedimentary rocks, the mountain forms corresponding in trend to the strike of the structure.

2. Plateau mountains, consisting of high subhorizontal plateaus void of serious deformation, occurring either as summits or as shoulders and attending higher relief features.

3. Mountains of igneous material, of three subtypes — old igneous vents (such as dikes and necks), craters, and summits of circumdenudation capped by sheets of ejecta.

Portions of these mountains have been elevated at different geologic epochs by various orogenic processes, but the group as a whole has also been elevated by general regional movements, so that its eastern base in the United States, adjacent to the western border of the Coastward Slope plain, now stands from 4000 to 5000 feet above the sea, the height of this line increasing northward; between the mountains and the coast is found the long and gentle descent of the Coastward Slope.

Although conspicuous and sharply defined relative to the plains from which they rise, these mountains, as a rule, with the exception of the Sierra Blanca of the Sacramento Range of New Mexico, do not rise to the heights of the Rocky Mountains to the north or of the Sierra Madre of Mexico to the south. This is due to the fact that they occur along the lowest belt of the Cordilleran platform which crosses the continent along the southern boundary of the United States.

The highest altitudes attained are in the mountains of the eastern Front Ranges. Sierra Blanca, of the Sacramento Range in southern New Mexico, reported to be 13,000 feet high, is the highest summit. The highest mountain of the system in Texas is Guadalupe Peak, near the New Mexican line — 9000 feet, or 5000 feet above the interior margin of the Coastward Slope plain. Southward the mountains do not attain high altitudes until they cross the Rio Grande in Mexico. Livermore Peak (8250 feet) and Mount Emory (9000 feet) are the highest summits south of Guadalupe Peak. Immediately upon crossing into Mexico the ranges again rise to higher altitudes — 10,000 feet or more.

The Trans-Pecos Mountains lack continuity and exhibit many irregular and eccentric forms of relief. In general the individual mountains present sharp and rugged outlines. They are usually barren of timber, except a few summits of the Sacramento, Davis (see fig. 46, Sheet VI, Types of Mountains), and Chisos mountains that rise above the base of the timber zone, which is about 6000 feet along the Rio Grande.

The individual mountains may be primarily classified as sierras, disconnected peaks (see fig. 25, Sheet III, Special Illustrations), and groups of peaks. The various mountain forms, whose lineaments are so clear in the arid atmosphere, have generally been given individual and descriptive names by the former explorers and inhabitants of Spanish speech. Thus we find them called by

[1] The word "tepetate," also spelled "telpetate," is a term used throughout Mexico and Central America for secondary non-marine deposits, either chemical or volcanic, forming a superficial coating over the country rock or impregnating the regolith. In Texas and northern Mexico the tepetate is always a chemical precipitate of lime, formed on calcareous soils or transported in solution and deposited through evaporation around the margins of desert basins.

[2] For a description of the process of distribution of the wash, see Nueces folio, No. 42, United States Geological Survey.

such names as cabezas (heads), cornudas (horns), chisos (ghosts), corazones (hearts), sandias (watermelons), sillas (saddles), cuchillas (knife-edges), etc. The term "cuesta" is also extensively used adjectively for the surface of a limited plain, plateau, or mountain which has a distinctly visible slope or tilt — a tilted mesa.

The writer does not assume to have seen all this vast Trans-Pecos Province. He has encircled it along the bordering valleys, has made journeys here and there into its desert plains, and has climbed some of its peaks and viewed its wonderful panoramas. The following descriptions are given with a consciousness that they are incomplete and that much remains to be ascertained concerning the region.

THE FRONT RANGES.

The east front of the Cordilleras, as the parting between the mountains and plains may be called, has a southerly trend from Colorado to the thirty-first parallel. From the latter line it curves southeast through Trans-Pecos Texas and northern Mexico, closely following in direction the general course of the Rio Grande toward the Gulf, which it reaches in Mexico near the northern tropic. This change in direction of the Cordilleran trend is due to certain orogenic processes which can not here be set forth, but it has an important bearing on the geography of the west Texas and north Mexican regions.

South end of the Rocky Mountains.—The Snowy Range of northern New Mexico, otherwise known as the Sangre de Cristo, is a direct continuation of the eastern Front Ranges of the Rocky Mountains of southern Colorado, and is the southern end of the Rocky Mountains proper, which mostly lie outside the Greater Texas region. In New Mexico, as in Colorado, the eastern border of the Snowy Range is marked by a low line of foothills of the type known as "hogbacks." The type of foothills extends south from the Colorado line near longitude 105°, through Las Vegas Hot Springs, and marks the border between the truly mountainous country and the plateau plains of the Las Vegas Plateau, to be described later. Both mountains and hogbacks end abruptly north of Bernal,[1] in latitude 35° 30′.

South of the termination of the main mass of the Rocky Mountains, at Bernal, there is a vast level cut plain or plateau, concerning which there is no accurate information, and which makes a distinct break in the continuity of the eastern Front Ranges of the Cordilleras and the Rocky Mountains of Colorado and northern New Mexico with the mountains of the Trans-Pecos group.

Sacramento Range.—About 100 miles south of Bernal, almost midway between the Pecos and the Rio Grande, in latitude 34°, lofty peaks again rise from this plain. These are the Jicarillas, which are the northern outliers of a chain of ranges that here sets in and extends almost uninterruptedly through New Mexico and Texas to the thirty-second parallel, and which, as a whole, may be called the Sacramento Range. The individual sierras of this group, beginning with the most northern, are known as the Jicarillas, Sierra Blanca, the Sierra Sacramento, and the Sierra Guadalupe. This group of mountains, which are the loftiest in the Trans-Pecos Province, varies in height and extent in different parts and is composed of lofty ranges with many peaks and lateral ridges extending toward the east. So far as known, the mountains are monoclinal in structure, sloping and dipping toward the Rio Pecos, where Carboniferous and Permian rocks form their substructure and Cretaceous strata their higher summits. Little or nothing is known of their simplest features, especially those portions lying within the Territory of New Mexico.

The Jicarillas are the most northern outliers of this chain of sierras. Southward they are succeeded by the Sierra Blanca, which culminates around Fort Stanton, where it compares in height and beauty with the true Rocky Mountains of northern New Mexico and Colorado. The highest summits, known as El Capitan, Sierra Blanca, and Nogales peaks, rise from 11,000 to 13,000 feet above the sea, and their upper slopes are covered with dense forests of pine.

The Sacramento Range, which succeeds the Sierra Blanca to the south, is a high crest extending northwest-southeast about 60 miles. It is partially bordered on the west by a mesa bench, which in turn overlooks a bolson desert. This range has never been surveyed and little can be learned concerning it.

The main trend of the Sacramento Mountains is continued southeast by a range known as the Sierra Guadalupe. The Guadalupe Range, as a whole, is a monoclinal uplift of Carboniferous rocks, sloping east, with a steep bluff to the west. This extends across the Texas line, where it culminates in a summit presenting a superb cliff to the south and west, known as Guadalupe Peak (see fig. 4). This cliff has a vertical face of nearly

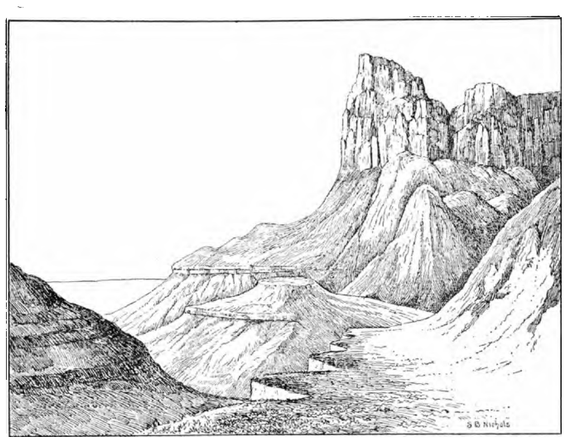

Fig. 4.—Guadalupe Peak, El Paso County, Texas. (After Bartlett.)

4000 feet, according to the measurements of this Survey. The peak itself is the highest in Texas, having an altitude of 9500 feet. From Guadalupe Peak the Guadalupe uplift, although continued by a line of decreasing summits which separate the Pecos Valley from the Howard Bolson, gradually dies out in a low mesa or swell to the south. No detailed maps or reconnaissances have been made of this portion of the uplift.

The Front Ranges become less definite and conspicuous for a distance south of Guadalupe Peak, in the vicinity of the Texas Pacific Railway, but from this railroad south their configuration and structure are more complicated and difficult to describe. The sierra configuration is apparently resumed as a higher and broader area of summits, known as the Davis Mountains. The Davis Mountains are not the Front Ranges, as many have been led to suppose, and as the writer until lately believed, but, as will presently be shown, they are great volcanic accumulations to the west of less conspicuous front ridges — the Comanche (Glass Mountain), Caballos, and Santiago sierras.

Comanche or Glass Mountains.—These are an elongated sierra, extending northeast, directly at right angles to the continental trend, from the meridian of 103° 30′ to that of 103°, and are composed of barren Paleozoic limestone and sandstone hills, probably capped on their highest points by Cretaceous limestone. They occur in a series of subparallel ridges dipping to the north, and rise to altitudes of 5600 feet, or about 1500 feet above the surrounding plains. They are intercepted on the west, at Altuda, by the Santiago Sierra, trending northwest-southeast. They are related to the Sierra Diablo Plateau, described later (see fig. 24, Sheet II, Special Illustrations).

Caballos Ridges.—These are low ridges of Paleozoic rocks rising from the floor of the Marathon Plain south of the Comanche Mountains. They should not be confused with the Sierra Caballos of New Mexico. They are composed of the degraded vertical edges of Paleozoic limestone, shales, and cherts, probably Lower Helderberg in age, occurring in closely folded, buckled ridges trending northeast and southwest. The cherts are often white in color and over 100 feet thick, and form the backbone of long, low ridges, such as the Peña Colorado, occupying the low area between the Santiago Sierra on the west, the Glass Mountains on the north, the Maravillas Plateau on the south, and the Stockton Plateau on the east. Caballos Sandia, a beautiful hill of white chert about 15 miles south of Marathon, is the highest of these summits, and rises about 1000 feet above the plain, to an altitude of about 5000 feet.

The Caballos and Glass mountains are exposures of ancient post-Paleozoic structure of Appalachian type and age, which have been revealed by the erosion of the Cretaceous sediments that probably once embedded them.

Maravillas scarp and San Francisco cuestas.—South of the thirtieth parallel, between longitude 103° and 103° 30′, the Marathon Basin, from the floor of which rises the Caballos Sierra, is bordered by a northward-facing scarp of subhorizontal Cretaceous limestone unconformably resting on the subvertical edges of the Paleozoic rocks. This scarp is surmounted by sloping plains (cuestas) dipping to the south, toward other similar parallel scarps. These cuestas are tilted fault blocks, with major faults extending about S. 70° E. They are the foothills of the higher folded mountains known as the Santa Rosa Mountains, which rise south of the Rio Grande as the northwest beginnings of the eastern Sierra Madre of Mexico and of the Santiago Range of Texas, presently to be described. The Rio Grande between longitudes 102° 30′ and 101° 30′ follows the trend of these faults.

Sierra de Santiago (Ord Range).—The Comanche and Caballos mountains and the San Francisco cuestas terminate westward against a long and narrow range of mountains which rise to altitudes of about 5500 feet and extend N. 30° W. and S. 30° E. from the Rio Grande to Altuda, on the Southern Pacific Railway. This mountain range consists of folded Cretaceous limestone, across which only one or two passable gaps are found. This long and narrow folded sierra is the only uplift in the Great Bend country having resemblance in trend and structure to the true Rocky Mountains, and represents the culmination by overthrow of areas of less strongly accentuated folds of the San Francisco cuestas. It is sharply terminated on the west by faults of the Great Basin type, which here produce a more conspicuous relief. Furthermore, as these faults diagonally cut the Santiago trend, the writer is of the opinion that the former relief of the eastern Front Ranges of Rocky Mountain type in this region has been largely obscured by the later forces producing the Great Basin structure.

INTERIOR RANGES.

West of the Front Ranges above described, which might appropriately be termed the mother sierras of the Trans-Pecos Mountains, other ranges set in, toward the Rio Grande, which are largely faulted blocks of the type known as the Great Basin structure. These occur as short sierras or groups of sierras arranged in elongate chains or as isolated peaks, surrounded by extensive subplevel deserts, apparently unrelated to other mountains — true "huerfanos," or orphans, as the Mexicans call them. These sierras west of the Front Ranges are narrower in outline and of lower altitude than the latter. Each individual sierra, peak, and cuesta has its own peculiar name, and our present knowledge is insufficient to fully interpret their relations to one another.

Interior sierras of New Mexico.—Beginning on the north, in New Mexico east of the Rio Grande, the chief sierras are the Sandia, Manzano, and Oscura, which occur in approximately north-south alignment, and the Sierra de los Caballos to the west. The Sandia and Manzano sierras collectively form a short desert range east of Albuquerque. The range as a whole extends north and south from nearly east of San Antonio on the Rio Grande, near latitude 35° 30′, to 75 miles south of the latitude of Socorro. Its north end terminates abruptly west of and nearly opposite to the southern end of the true Rocky Mountains, and forms a narrow divide between the Sandoval and Albuquerque basins. Its northeastern end flexes into the Galisteo Mesa, and its southern end terminates in the Mesa Montoso northeast of Socorro.

The Sierra Oscura chain begins near the thirty-fourth parallel, about 50 miles south of the southern end of the Sandia block, and extends southward to the Rio Grande at El Paso. Beginning at the north, the sierras of this chain are known as the Sierra Oscura, the San Andreas Range, the Organ Mountains, and the Franklin Range. Narrow and elongated as these mountains appear on the map, they have considerable altitude. The highest peak of the Oscuras, according to Wheeler, rises 8732 feet above sea level. Salinas Peak, marking the northeastern end of the San Andreas, is 9040 feet high. The Organs reach 8000 feet. In its northern portion the Oscura chain is transected by narrow longitudinal valleys, one of which separates the northern end of the San Andreas Sierra from the Oscura Sierra to the east. This narrow line of sierras forms a barrier between the Hueco Basin on the east and Jornado del Muerto and Mesilla basins on the west. These mountains are largely composed of Archean and Paleozoic rocks, and present some evidence of being an older group than the Cordilleras of the eastern Front Ranges. The axis of the Sierra Oscura far exceeds in length the other ranges lying west of the Front Ranges of the Cordilleran region.

West of the Oscura trend, and mostly beyond the Rio Grande, there are other sierras which become less and less capable of union into related chains and assume the type of short independent blocks surrounded by bolson deserts. Only one block of this type lies east of the Rio Grande within the area of the map. This is called the Sierra San Cristobal, and lies along the western edge of the Jornado, where the Rio Grande makes a westward deflection in its general southward course. It is composed of two north-south ranges, known as the Sierra San Cristobal and the Sierra Caballos, respectively. These blocks collectively extend through only one degree of latitude. They might theoretically be connected across the interval of plain to the north with the Socorro and Ladrone mountains west of the Rio Grande, but no attempt will here be made to connect them into systems.

Interior mountains of Trans-Pecos Texas.—It is difficult, with our present knowledge, to describe or systematize the interior mountains of Trans-Pecos Texas west of the east-front uplifts (the Guadalupe and Santiago mountains), for in this region there arise between the diverging Front Ranges on the east and the Oscura trend on the west a number of dissimilar and eccentric mountain forms of diverse origin. These consist of solitary peaks, short sierras, areas of elevated plateaus, great buttes and cuestas, and groups of gigantic volcanic necks and dikes. Some of the sierras are so aligned as to suggest long axial lines of uplift; others are so peculiar in occurrence that they defy all attempts at classification.

The sierras forming the Oscura chain cross the Rio Grande at El Paso and continue on the Mexican side south of that river. Between this range and the eastern Front Ranges there is but one orogenic feature suggestive of a long, continuous mountain trend. This is initiated on the north at the Texas–New Mexico line, at the one hundred and sixth meridian, between the Oscura and Guadalupe ranges, by the Hueco Mountains, which are in alignment with other mountain ranges extending to the Mexican boundary and which continue southeast until they cross the Rio Grande between the thirtieth and thirty-first parallels near the one hundred and fifth meridian. This apparent chain of sierras is known by different names in its several parts. Beginning at the northwest these are as follows: Hueco, Finlay, Quitman, Eagle, and Vieja in Texas, and the Sierra Rica in Mexico, near Presidio del Norte. Each of these names is applied to a separate sierra or mountain block, cut off from its neighbors by low passes. These mountains rise from desert plains and in general present a steeper summit to the west than to the east. In structure they are largely faulted monoclines, although in places the folding is extensive. The rocks composing them are also of different ages in the different sierras. It is probable that the southern extension of the feature thus described as a single chain will prove to be a parallel chain on further investigation.

The Hueco Sierra is composed of granites and older Paleozoic rocks. The Finlay Mountains present Jurassic limestone in their western base—

[1] See Bernal and Lamy sheets of the Topographic Atlas of the United States, published by the United States Geological Survey.

the only known occurrence of rocks of this period in the Texas region — with Lower Cretaceous limestone above them.

In the Quitman and Eagle Mountains Paleozoic (Carboniferous) limestone, surmounted by Lower Cretaceous limestone and Upper Cretaceous clays and sands, are found. The Sierra Vieja is composed of Upper Cretaceous shales and sandstones, with vast thicknesses of interbedded rhyolites, and, according to Vaughan, capped by a volcanic material known as quartz-pantellerite.

Between these trends and the eastern Front Ranges (Guadalupe-Santiago trend) there is a belt of broken plain, averaging 50 miles in width and from 4000 to 5000 feet in altitude, from the floor of which, except in the northwestern portion, where it is occupied by the Diablo Plateau, rise several remarkable and eccentric volcanic mountain groups. This plain, at least toward the Rio Grande, is sharply defined on both sides by fault lines — on the east by faults with western downthrow which follow the west side of the Santiago Sierra in Texas and of the Sierra del Carmen in Mexico, and on the west by faults with eastern downthrow which follow the Santa Helena Plateau, an unmapped and undescribed relief feature through which the so-called Grand Canyon of the Rio Grande cuts its way.

The Sierra Diablo Plateau is an extensive subhorizontal mesa of Carboniferous limestone which Von Streeruwitz describes as a part of an old Paleozoic highland that was never capped by Cretaceous sediments. This plateau attains a height of about 4000 feet above the level of the plain, and is structurally related to the Guadalupe, Comanche, and other features of the Paleozoic area of the northern part of Trans-Pecos Texas. It presents a steep scarp toward the Salt Basin on the east and the Texas Pacific Railway on the south. A view of its topography is shown in fig. 36, Sheet II, Special Illustrations.

South of the Diablo Plateau many volcanic mountains rise from the floor of the broad belt of the plain. Of this type are several groups covering extensive areas, such as the Davis, Chisos, Chinati, and Corazones mountains, and isolated summits like the Sierra Blanca. Some of these mountains rise 4000 feet above the plain.

Of these groups the Davis Mountains, originally called the Apaches, are the most extensive. They occupy a large, irregularly oval area between the thirtieth and thirty-first parallels, the configuration of which is shown on the Fort Davis and Alpine sheets of the United States Geological Survey. The Davis Mountains consist of an extensive group of igneous necks and the mesas of adjacent dissected volcanic plateaus. The highest of the necks, which are largely conical loaves or peaks, rather than continued crests, rise to altitudes of more than 8000 feet and occur along the western margin of the group. Each of these is given a local name, such as Livermore Peak, Puertacitas, Mitre Peak, Twin Mountain, Cathedral Mountain, Cienaga Mountain, and Goat Mountain. The mesas and cuestas of the dissected plateau mostly occupy the eastern area of the group. The group as a whole terminates at the south with a great escarpment, over 1000 feet in height, overlooking the continuation of the intermontane plain to the south.

About 50 miles south of the Davis Mountains another group of volcanic peaks, known as the Corazones, rises from the plain. This consists of picturesque, rugged, conical points, heads, and pyramidal forms, occupying a field about 25 square miles in area and rising about 1500 feet above the surrounding plain, or to altitudes of about 5500 feet. They are composed of white rhyolite which weathers into brilliant orange colors. Near the Corazones Peaks are several smaller groups of similar mountains. Some of these are without names. The Rosillos (red) Mountains lie east of the Corazones and north of the Chisos.

About 25 miles southeast of the Corazones, in the apex of the Big Bend of the Rio Grande, is the Chisos group (see fig. 27, Sheet III, Special Illustrations). This is composed of a dozen (more or less) peaks of vertical rhyolite, rising to altitudes of nearly 9000 feet, or 6500 feet above the river at their base. In Texas they are exceeded in altitude only by Guadalupe Peak. Their summits often present vertical escarpments nearly 1000 feet high, while the bases of the mountains are buried in talus derived from the degradation of the peaks. The upper portions are covered with forests of oak, pine, and cedar.

Besides these groups of peaks, there are many single eminences (cabezas and sandias) of reddish rhyolite standing solitary in the desert. Of this type are Sierra Blanca (see fig. 25, Sheet III, Special Illustrations, and fig. 43, Sheet VI, Types of Mountains), near the railway station of that name, and Red Mountain, "G4" Mountain, and Mount Hobson, outliers of the Corazones. Still others, like Santiago Peak (altitude 6800 feet), Jascatl, and San Jacinto, are graceful cones of black basalt.

Still another type of these mountains are the gigantic mesa- and cuesta-topped buttes of circumdenudation, capped by masses of old igneous ejecta over 500 feet in thickness. These are remnants of former sheets of similar material, which have been preserved by circumdenudation of the adjacent areas and are bordered by precipitous scarps. Of this type may be mentioned Elephant Cuesta, at the southeast corner of the Alpine quadrangle; Ninepoint Mesa (see fig. 32, Sheet IV, Special Illustrations), about 30 miles north of the Chisos, and several unnamed eminences of similar configuration. The summits of some of these, such as Ninepoint and Elephant mesas, are 10 square miles or more in area. These phenomena collectively constitute the manifestation of late Tertiary volcanic outbreaks along a faulted belt of country between the Oscura and Santiago trends.

Santiago Peak, by reason of its isolated position near the eastern edge of the intermontane plain, 35 miles southwest of Marathon, is one of the most conspicuous landmarks in Trans-Pecos Texas. It rises 1500 feet above the plain, and is only a mile distant from the sharp fault line which separates the plain from the western side of the Santiago Mountains.

There are many other features of this region which can not be described at present, but which the author hopes to make the subject of a special paper in the near future.

Volcanoes.—Besides the older relief forms resulting from combined volcanic and degradational agencies above described, there are other volcanic phenomena of more recent date constituting exceptional but interesting features of the bolsons and plateau plains of the Trans-Pecos region. These are true volcanic craters or cinder cones, accompanied by sheets of lava which flowed from them, locally known as "malpais."

From the lower Las Vegas Plain and along the southern foot of the Mesa de Maya in northeastern New Mexico rises a group of true volcanic craters consisting of cinder cones standing from 1000 to 2750 feet above the plain. From these have been extruded sheets of basaltic lava which cover the country for miles around and extend more or less irregularly from Folsom to Rabbit Ear Hills, near the Texas line. The most conspicuous of these craters is Mount Capulin, 6 miles south of Folsom station. This is a beautifully symmetrical cinder cone, in the top of which is a vast crater. From its summit, looking southward, can be seen many similar craters, from 6 to 20 miles distant. These craters are of interest because they are the most eastern known in the United States and the only ones lying east of the front of the Cordilleras. These cinder cones have clearly been extruded since the degradation of the Mesa de Maya and Ocate plateaus, for they rise out of the newer and lower plain below them.

West of Santa Fe is another lately extinct volcanic cone, rising from the Galisteo Mesa. This cone has been described by Marcou as follows:[1]

> It is named Cerrito, and is situated in the middle of the Rio del Norte Valley, as a connecting link between the sierras of Santa Fe, Yemez (Jamez), Sandia, and Placeras. This ancient volcano is not very elevated, the different cones of which it is composed being only 800 or 1000 feet above the plateau from which they rise. The lava extends over the whole country between the rivers Galisteo, Cieneguilla, and Naule, and the pueblos of Cochiti and San Felipe; the ranches of Cerrito are even at the bottom of the crater. The Rio del Norte and the Rio Bajado, or Cieneguilla, have made their beds in the lava of the crater, and in the sections discovered by these means it is seen that the streams of basaltic lava have re-covered the drift and in some places have even changed it into volcanic conglomerate. Between the Rio Grande and the Rio Puerco, a little north of Albuquerque, there is a volcanic cone whose lava extends over the sandstone and whose streams are seen as far as the old pueblo of San Felipe, on the top of the hill opposite the town of Albuquerque and on the right side of the road from Albuquerque to the Rio Puerco.

[1] Geology of North America, by Jules Marcou, Zurich, 1858, p. 22.

Another extinct volcano is found at the head of Franklin Basin. This consists of low cinder cones at the extreme northern end of the basin, from which a long ribbon of lava has flowed southwest over the desert plain for 70 miles, making the noted "malpais" crossed by the highway from Carthage to Fort Stanton. This has been mapped by Wheeler and briefly described by Tarr. The Wheeler Survey mapped another cinder cone in the Stanton Mountains, east of Sierra Blanca, but no description of it is known.

THE PLAINS.

By far the larger portion of the Greater Texas region is occupied by plains, and, as these are diverse in structure and relations, their character may best be understood by a few preliminary words on the nature and origin of plains in general.

The term "plain," while applied to a region which is dominated by a conspicuous and persistent subhorizontal surface, is not always intended to signify an unbroken monotonous physiographic feature absolutely without relief. It is true that some of the districts in the Texas region to which the term is applied are vast level stretches approximating as nearly as is found in nature a theoretical plane. But every plain, however level it may appear, presents within its area or as bordering phenomena some inequalities of configuration, such as valleys and rises, while some of the plains to be described are so rugged as to be locally classified as mountainous. The plains herein described are, by origin, of two broad types, constructional and destructional.

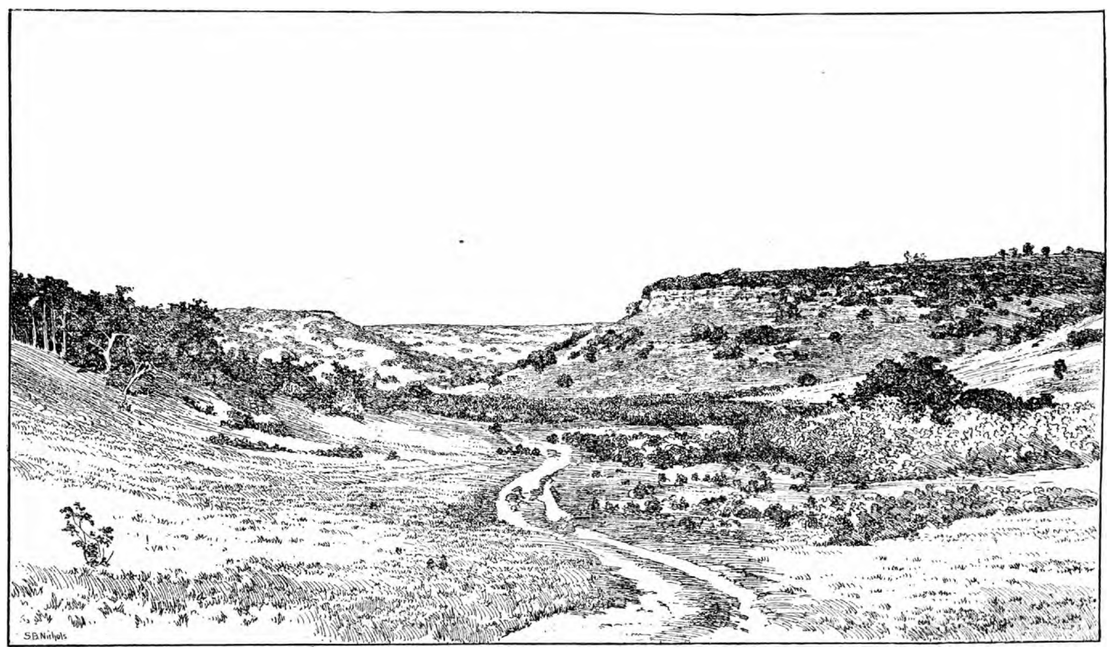

Fig. 5.—View in Lampasas County, Texas, showing a cut plain.

CONSTRUCTIONAL PLAINS.

Constructional plains owe their origin and present surface features principally to the distribution and deposition of earth material in sublevel sheets along the streamways or at the margin of the ocean, or to the distribution of lava sheets or other volcanic ejecta over the surface. Destructional plains originate in the degradation (or planation) of older and higher surfaces down to a lower level.

Destructional plains are sometimes evolved from constructional plains; the latter, after elevation and long erosion, are reduced in old age to the former. On the other hand, constructional plains are usually established upon areas which were once destructional plains. Ancient buried destructional plains thus veneered by constructional formations might be appropriately termed *paleoplains.*

Constructional plains may be either sea-made or land-made. In the former case, with certain minor exceptions like the surfaces of coral reefs, they are land-derived sediments which were once distributed and deposited in the littoral and sublittoral waters around the margins of the land. In the latter case they are composed of lake and river sediments or débris brought down by freshets and distributed over the surface of a pre-existing older plain at the foot of higher regions, such as mountains and escarpments.[1]

There is one great sea-made constructional plain in the Coastward Slope region of Texas. This is the Coast Prairie, which borders the present Gulf shore. It is a young plain, and represents the old deposition surface, which has been but slightly elevated above the sea.

Of land-made constructional plains there are many examples in the Texas region, two of which — the Llano Estacado and the Rio Grande embayment — are conspicuous (see fig. 52, Sheet VII, Types of Plains and Scarps). Both of these are imposed upon old destructional plains, to which condition they are again being reduced by erosion. Many of the bolson plains of the Trans-Pecos Province are constructional plains.

The Llano Estacado is a constructional plain veneering an old destructional plain. The surface formation is land-made and is composed of talus and wash derived in Tertiary and later time from the higher Cordilleran regions to the west; it has been redistributed over and over again by the process of sheet-flood and wind erosion. On the west, north, and east margins this plain has been eroded so that it now stands above lower-lying destructional plains situated in those directions. Southward it merges into the destructional plain of the Edwards Plateau, which is a re-exposure of the old paleoplain that makes the foundation of the Llano Estacado to the north.

The plain of the Rio Grande embayment occupies a low synclinal trough between the Balcones escarpment and the east front of the Mexican extension of the American Cordilleras. Its constructed surface consists of the sheet-flood débris (wash) of the two border regions — the Edwards Plateau on the north and the Mexican Cordilleras on the south. The surface of the Rio Grande Plain is now dissected into low summit areas occurring as wide divides between the streams. By destruction it is being graded down toward the level of the Coast Prairie.

There are also many notable constructional plains in the Trans-Pecos region, which will be more fully described later.

DESTRUCTIONAL PLAINS.

Other extensive plains of the Texas region, such as the Edwards Plateau, the Central Province, and the East-Central Province, are destructional plains and are the result of leveling by erosion processes, by which an older relief is reduced toward a lower horizon or plain, upheld by the resistance of a relatively more durable stratum. These destructional plains may again be classified into several minor types of stratum plains.

Stratum plains are level or sublevel surfaces the configuration of which is conformable to a

[1] See description of the "wash" in the Nueces folio, No. 42 of the folios of the Geologic Atlas of the United States, 1898.

rock sheet which is relatively hard and therefore more resistant to erosion than are the adjacent rock sheets. There are three well-marked varieties of stratum plains, viz: mesa plains, dip plains, and cut plains.

A mesa plain is the flat summit of a hilly mountain or plateau of circumdenudation or of a mesa bench. Such phenomena are elements of a cut plain (see fig. 5, p. 5).

A dip plain is an inclined stratum plain, the surface slope of which coincides with the dip of the upholding stratum.

Mesas are either the horizontal summits of plateau plains completely circumdenuded or benches of level plain abutting against a background of higher relief. The term "mesa," meaning a "flat surface on the top of hills or mountains," signifies a quality of a relief feature rather than the whole feature. Thus a flat-topped butte is often called a mesa, when in fact the mesa may be only a feature of the butte as a whole.

The term "cuesta," meaning a slope, is used similarly to the word mesa, as an attribute of a relief form, signifying a flat summit surface which is tilted rather than horizontal (see fig. 32, Sheet IV, Special Illustrations, and fig. 53, Sheet VIII, Types of Plains and Scarps).

A cut plain (dissected plain) is a stratum plain of any kind which has been so dissected into remnants by erosion that the level of the original stratum plain is still recognizable in the summits of the dissected members (see fig. 49, Sheet VII, Types of Plains and Scarps).

The term "rolling prairies" is well established by popular usage in Texas for plains of undulating or rounded hilly relief, as distinguished from flat plains. Such plains are usually built upon unconsolidated strata of clays or sand (see fig. 58, Sheet VIII, Types of Plains and Scarps).

The plains of the Texas region may be geographically classified into two groups: the plains of the Regional Coastward Slope and those of the Trans-Pecos Province.

PLAINS OF THE COASTWARD SLOPE.

The term Regional Coastward Slope is here used for all the non-mountainous portions of the Greater Texas region, including the Great Plains and the Central, East-Central, and Southern provinces.

Before the individual plains of the Regional Coastward Slope are separately discussed its broader features will be considered. As a whole it has a general eastward slope from the foot of the Cordilleras to the coast, from an altitude of 4000 feet or more to sea level. This slope is primarily caused by a tilt, or the sum of several tilts, which the region has received through uplifts of the Cordilleran region in Tertiary and later time. The slope of the coastward plain north of the twenty-ninth parallel is to the east, and in a direction at right angles to the east front line of the Cordilleras north of the thirty-second parallel. Between the twenty-ninth and thirty-third parallels the slope continues east as far as the interior borders of the Eastern and Southern provinces. Within these provinces the direction of the slope changes to the southeast. The first-mentioned direction of the slope pertains to the Great Plains region in general, and the second to the more restricted coast plains proper. South of the thirty-second parallel the gradient of the Regional Coastward Slope is adjusted to the curve of the mountain front in a peculiar manner. Normally it should change in direction sympathetically with the curve, but, instead, it continues east, in a direction no longer at right angles to the mountain front, until the twenty-ninth parallel is reached. At the latter parallel the uniformity of direction of slope is suddenly replaced by the structural deformation of the Rio Grande syncline, making a low synclinal basin between the Balcones scarp and the Mexican Cordilleras.

The general average inclination of the Coastward Slope from the mountains to the sea is 8.7 feet per mile. It varies in the different provinces, being approximately 8.6 feet per mile across the Llano Estacado, 9 feet across the western part of the Central Province, 6.7 feet across the eastern part of the Central Province, 16 feet across the Grand Prairie, 2.5 feet across the Black Prairie and the East Texas timber belt, and 1.3 feet per mile across the Coast Prairie.

The chief relief feature of all the plains of the Coastward Slope is their general inclination toward the sea, in conformity with the tilt or dip of the underlying strata, away from the Cordilleran front, caused by the regional upward movements of the Cordilleran area as a whole, as mentioned elsewhere in this paper.

The relief of the individual plains is due to differences in origin, age, adjustment of erosion to the different geologic formations, climatic conditions (such as wind, humidity, precipitation, and evaporation), and gradient of the regional slope. Some plains, like the Coast Prairie, are so nearly flat and unbroken that undulations or elevations can hardly be detected; others, like some belts of the Central Province and the margin of the Edwards Plateau, are deeply and extensively dissected into high hills of uniform elevation separated by valleys, so that only small remnants of the former surface are here and there preserved; still others, like the eastern and southern extension of the Black Prairie, are eroded into low, rounded hills called rolling prairie.

The plains of the Regional Coastward Slope are of four general types, forming wide belts extending in approximately north-south directions. These are the Great Plains proper, the central prairies, the plains of the East-Central Province (the Black and Grand prairies), the Atlantic timber belt, and the Coast Prairie. They may be classified by relationship into three major groups: the Great Plains, the prairie plains, and the coast plains.

The Great Plains are a wide north-south belt of sublevel highland extending east from the Rocky Mountains to the prairie plains. The prairie plains consist of the plains of the Central Province and the Grand and Black prairies of the East-Central Province. They occupy an intermediate position between the coast plains and the Great Plains proper, and they differ from these in many respects, as will be shown later. The coast plains, including the Coast Prairie and the East Texas timber belt, form a wide stretch of lowland extending west from the Gulf.

The most conspicuous relief features of the plains of the Coastward Slope are the Plateau of the Plains, the bordering Breaks of the Plains, the valleys of the plains, the Callahan Divide, the Balcones fault line, the Anacacho Hills, the Llano Hills, the Shumard Knobs, and the White Rock, Grand Prairie, Baird, and Seymour scarps, which will be described in the specific descriptions of the plains to which they are related.

The Great Plains.

The Great Plains Province within the area of our map includes a portion of the middle and all of the southern part of the Great Plains region. The middle division, which is locally known as the North Plains, lies between the Arkansas and the Canadian rivers. The southern division is a relief feature which we shall term the Southern Plateau of the Great Plains.

The Southern Plateau of the Plains (the combined Llano Estacado and Edwards Plateau) is the most extensive relief feature of the non-mountainous portion of Texas. It represents the continuation of the Great Plains proper south of the Canadian Valley, and is a vast subquadrangular, treeless table-land, some 60,000 square miles in area, slightly tilted toward the sea and surrounded on all sides by escarpments of erosion. At one time it was a continuous plain which extended from the front of the mountain eastward far across the Central Province. Denudation of its margins has restricted the area to its present dimensions. It is surrounded by the escarpments of the deeply eroded Pecos Valley, separating it from the mountains on the west, the drainage groove of the Canadian on the north, and an escarpment of head-water recession on the east. Its southern margin is abruptly terminated by the Balcones fault escarpment, coastward of which the level of the country has dropped several hundred feet. In this manner the Plateau of the Plains has become a subquadrangular plateau surrounded by low escarpments, which are locally known as the Breaks of the Plains.

LLANO ESTACADO.

That portion of the summit of the plains north of the thirty-second parallel is known as the Llano Estacado, and the portion south of the parallel as the Edwards Plateau. The Llano Estacado is a vast region so nearly level that it has no relief perceptible to the eye. Its extreme northwestern corner (in New Mexico) has an approximate altitude of 5000 feet, and its slope is about 8.6 feet per mile eastward. The general flatness, which continues up to the very brink of its surrounding escarpments, is marked only by long swales, like the faintest troughs of the gentler swells of the ocean, and the depressions are so slight that their shallowness has been appropriately described by Castañeda, the historian of the Coronado expedition, as being "like a bowl, so that when a man sits down the horizon surrounds him on all sides at the distance of a musket shot" (see fig. 29, Sheet III, Special Illustrations). These shallow depressions are produced by underground solution and the erosive action of the wind. The summit is composed of a porous, unconsolidated formation of sand, marl, and gravel, of Tertiary and later age, the ancient wash from the western mountains, deposited upon a foundation or floor of the friable Permian Red Beds and Cretaceous limestone. The general flatness is maintained by the local storm floods upon the low slope, which, instead of establishing permanent drainage canals, tend to level the slight irregularities of relief by erosion and to fill up the depressions by sheets of flood-wash débris. The action of high winds on the normally dry unindurated surface material both levels and creates inequalities.

The summit of the Edwards Plateau is a great stratum plain of Edwards limestone thinly veneered by residual calcareous soils, and is faintly marked by gentle draws leading out to its bordering scarps, where they deepen into box canyons (see fig. 48, Sheet VII, Special Illustrations, and fig. 57, Sheet VIII, Types of Plains and Scarps).

BREAKS OF THE PLAINS.

The scarps which border the Plateau of the Plains are not less interesting than its summit. These are known as the bordering Breaks of the Plains. The eastern breaks are a ragged line of low scarps overlooking the denuded Central Province (see fig. 6; also fig. 48, Sheet VII, Types of Plains and Scarps). These extend in an irregular curve from south-central Kansas westward, then southward through Oklakoma and Texas, west and south of the Central Province, to the Colorado. Their continuation northward from the Colorado becomes the westward-facing scarp of the

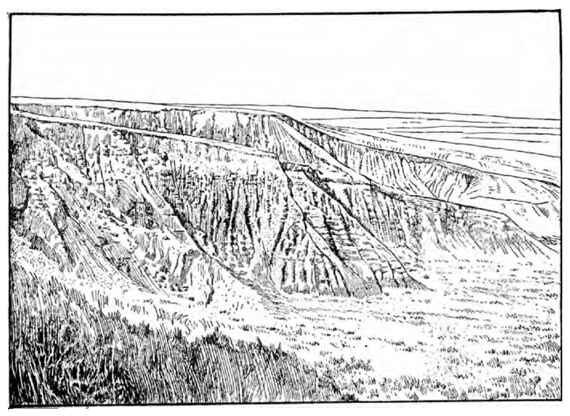

Fig. 6.—The Breaks of the Plains.

Grand Prairie, and nearly completes a subcircular line of low scarp lines almost surrounding the Central Province. The scarps, especially to the south, are of the compound type, consisting of benches and slopes of stratification. They seldom exceed 800 feet above the deeper drainage cuts. North of the thirty-third parallel they are composed of impervious Red Beds at their base (the Permian) and of lighter-colored pervious beds (the Plains formation) at their summit, with here and there an occasional patch of the shales and limestones of the Cretaceous preserved between them. South of the Brazos the Edwards limestone enters into the material of the scarp line, and finally dominates its structure in that direction. These eastern escarpments are produced by the receding headwater erosion of the streams of the Central Province.

The Balcones scarp.—The southern breaks of the Plateau of the Plains form the Balcones fault scarp (see fig. 51, Sheet VII, Types of Plains and Scarps). This extends from the Colorado at Austin to west of Del Rio, on the Rio Grande, and its summit is from 300 to 1000 feet above the lower Coastal Plain, the relative altitude increasing westward. This scarp line, produced by a zone of faulting in Tertiary time, is now greatly indented in places by the canyons of the numerous streams flowing across it from the plateau into the Coastal Plain. With the exception of the few volcanic necks which occur along its base, it is the only relief feature of the greater Coastward Slope plain produced by other agencies than erosion.

The western breaks of the Plateau of the Plains are an inward-facing escarpment of stratification overlooking the longitudinal parting valley of the Pecos. North of the thirty-first parallel it surmounts a long and gentle slope between it and the river; south of that parallel it makes a steep limestone canyon separating the Edwards Plateau from the Stockton Plateau.

STOCKTON PLATEAU.

This is a subdivision of the Edwards Plateau which lies west of the Pecos and east of the eastern Front Ranges. The scarps of the northern edge of this area overlook the Toyah Basin, while its southern border is tilted and faulted into low monoclinal blocks—the beginnings of the ranges of northern Mexico.

OUTLIERS OF THE GREAT PLAINS.

The former extension of the Plateau of the Plains westward to the mountains and eastward far over the Central Province is attested by hills of circumdenudation forming outlying remnants of the plateau. These are found to the northwest in New Mexico and to the east in the Central Province, occurring as isolated, circular, flat-topped hills or as groups of hills between the principal drainways (see fig. 26, Sheet III, Special Illustrations, and fig. 33, Sheet IV, Special Illustrations). The summits are all of the same geologic formation as the adjacent plateau and are in vertical alignment with its normal coastward slope. Those to the east belong geographically within the Central Province, elsewhere described.

VALLEYS OF THE GREAT PLAINS.

The canyons of the Great Plains are of two types: first, those which indent the eastern border of the plains; second, those which completely cross the plains, severing them from adjacent regions.

The canyons of the first type are the streamway indentations into the plains leading back from the eastern breaks. Most conspicuous of these is the canyon of Red River. This is a steep box canyon with a wide, flat bottom. It is nearly 100 miles long and about 900 feet deep in parts, and is terminated inland by a steep fall line. In such scenic features as variegated colors and the differential erosion of the horizontal strata of its steep walls it is somewhat similar to the Grand Canyon of the Colorado of the West. The canyons of the various forks of the Brazos, Colorado, Concho, Frio, Nueces, and other streams indenting the eastern and southern borders of the Plateau of the Plains, while not so deeply cut as the canyon of Red River, are all of the same general type.

There are two great stream valleys of the second type which are established in valley plains completely severing the Plateau of the Plains. The valley of the Canadian is the northern breaks of the Plateau of the Plains. This is a deep groove extending completely across the province, separating the Llano Estacado proper from the extension of the Great Plains Province to the north. The composite Pecos Valley, which separates the Plateau of the Plains from the mountain and mesa country to the west, is a long and deeply scored parting valley (see fig. 47, Sheet VII, Types of Plains and Scarps) whose slopes and plains

form a large district established below the general level of the plains and mesas.

The Pecos Valley in New Mexico, immediately east of where the stream leaves the mountains and the Las Vegas Plateau, is a wide region of lower plain locally called a plaza. This consists of many miles of level plains extending between the surrounding cliffs of the Llano Estacado on the east and those of the central mesas interiorward. This valley is not one continuous plain, but a series of stratum plains cut out of stratum plains—plazas within plazas, leading down to the little stream valleys of the Pecos and Canadian, which are entirely disproportionate to the width and extent of the greater valley of the plaza region as a whole.

The great plaza country of the Pecos as far south as the Guadalupe Mountains is established upon a continuous stretch of Red Beds country veneered by many terraces of Tertiary or Pleistocene alluvium. Here and there, where gypsum strata form the floor, this material has crumbled into a white powder, known as "jeso," which covers the ground like snow. In other places the valley slopes are occupied by sand hills and alluvial deposits of Pleistocene age.

Between Roswell and Eddy the mountains send low spurs toward the river, separating the greater valley to the north from another wider portion in the vicinity of Eddy and the Seven Rivers.

Near the Texas line there is another mountainous constriction, south of which begins what may be known as the Toyah Basin of Texas. This lies between the western border of the plateau of the Llano Estacado and the mesa benches of the Guadalupe Mountains. To the south it is restricted by the escarpments of the Edwards and Stockton plateaus. This country differs from the plaza region to the north in that its soil is composed largely of alluvial loams. The Toyah Basin is an extensive bolson desert, established far below the general level of the Edwards and Stockton plateaus. Several small lakes without outlet still occupy this plain. This may at one time have been a lacustral area into which the Pecos emptied, and which was subsequently captured by a tributary of the Rio Grande.

At the southern end of the Toyah Basin the Pecos enters a narrow box canyon cut below the level of the Edwards Plateau, in which the stream continues to the Rio Grande.

Prairie Plains.

The prairie plains, which include the vast Central Province of southern Kansas, Oklahoma, Indian Territory, and Texas and the East-Central Province of Texas, primarily consist of destructional plains resulting from the wearing away of the formations of the Coastward Slope from higher to lower beds. The general type of relief is that of a greatly denuded prairie region in which the surfaces have been established upon many different planes of stratified rocks, some of which are very rugged, although extensive stretches of level prairie predominate. These stretches occur mostly in subparallel north-south belts of country accompanied by scarp lines, isolated circular buttes and mesas, and deeply serrated cut plains. This relief is due to erosive sculpture resulting from the establishment of the natural drainage upon successively lower and lower stratum plains in the geologic series from the Plains (Tertiary) formation on the west to the Algonkian at the southeast, inclusive. In a broad way this relief may be looked upon as a great and deeply cut intaglio, in which the various surfaces, composed of layers of six groups of subhorizontal strata of different age, thickness, hardness, and color, have been successively exposed by erosion.

Plains of the East-Central Province.

The East-Central Province is composed chiefly of the Black and Grand prairie belts of Texas and southern Indian Territory, each bordered on the west by a belt of upland timber known as "Cross Timbers." These are parallel north-south belts of dip plains developed upon the outcrops of the various Cretaceous formations. The latter are a series of marls, sands, and limestones, inclining to the east so gently that their dip is only slightly greater than the inclination of the Regional Coastward Slope. Such an arrangement produces broad areas of outcrop. The topography of the Black Prairie, established principally on the marls, is undulating. The topography of the Grand Prairie is established upon beds of firm subhorizontal limestone of vast areal extent. These limestone surfaces are mostly flat dip plains, passing into cut plains along their interior margins. They slope gently eastward, and are terminated coastward by low inward-facing escarpments of stratification of the next plain. The plains are faintly indented by drainways that are fed by longitudinal branches whose ultimate and active caletas rise along the inland-facing escarpments.

The interior of the Black Prairie is marked by a low inward-facing escarpment of stratification which extends south from Sherman toward Austin. Although this does not exceed 200 feet in altitude, it is a marked break in the otherwise uniform surface of the adjacent areas. It is an outcrop of the Austin chalk, the only conspicuous semi-indurated beds between the interior margin of the Black Prairie and the sea. Its margin overlooks the narrow belt of the Eastern Cross Timbers.

The western or inland-facing escarpment of the Grand Prairie (see fig. 55, Sheet VIII, Types of Plains and Scarps) is a still more conspicuous feature in the Texas region, extending as it does from the boundary of Arkansas due west through Indian Territory to the ninety-eighth meridian, and thence south through Texas to the Colorado, in a much-lobed and crenulated line. From the Colorado it curves west around the southern edge of the Central Province, where it becomes the eastern escarpment of the Plateau of the Plains.

North of the Brazos the slopes of this escarpment, marked by many low stratified terraces, descend to the west at a low gradient and include the Glen Rose type of prairie, consisting of open stretches of country and the various upland belts of the Western Cross Timbers, which follow certain outcrops of sandy strata. The crests of this escarpment are produced by an outcrop of the Edwards limestone; its hardness relative to that of the underlying formations results in its preservation as the summit of the escarpments and as many circular outlying remnantal buttes, usually known as round mountains, along the western border of the Grand Prairie and at widely disconnected intervals over the Central Province, as described later. This limestone stratum caps also the southern (Edwards) portion of the Plateau of the Plains, into which the Grand Prairie merges south of the Colorado.

Plains of the Central Province.

The Central Province in its entirety includes the vast region between the Plateau of the Plains on the west and south and the Missouri, Ozark, and Grand Prairie countries on the east. It consists of two great divisions separated by the Ouachita Mountain system—the northern or Kansan, and the southern or Texan. The northern area comprises various belts of prairie plains in Oklahoma, Indian Territory, and southern Kansas, closely allied in origin and nature and often continuous with those of the southern area. In this paper the latter only can be considered. This is bordered on all sides except the north by receding escarpments of erosion. On the west and south these are the eastern breaks of the Plateau of the Plains; on the east they are the western scarps of the Grand Prairie.

Callahan Divide.—The highest relief features of the Central Province in Texas are the numerous flat-topped, circular, remnantal hills (mesa buttes) which are outliers of the Plateau of the Plains and of the Grand Prairie (see fig. 33, Sheet IV, Special Illustrations; also fig. 59, Sheet IX, Types of Plains and Scarps). These are capped by the hard Edwards limestone. Upon some of the most western of these are found gravel and other remnants of the Plateau of the Plains. The altitude of these mesas averages 500 feet above the principal drainways, and about 250 feet above the highest of the several intervening plains.

The remnantal mesas occur at widely separated intervals over that portion of the Central Province which is south of the northern headwater forks of the Brazos. Although widely distributed, they form less than 10 per cent of the total area of the Central Province. The principal group, which may be termed the Callahan Divide, occupies the watersheds of the Brazos and Colorado, lying approximately along the thirty-first parallel, and extends, like thickly set bridge piers, from the western border of the Grand Prairie west to the Plateau of the Plains, through Comanche, Brown, Eastland, Callahan, Coleman, Taylor, Runnels, and Mitchell counties. There are many similar isolated remnants north and south of this line, separated from one another by great areas of lower-lying plain, such as Double Mountain, in Stonewall County, and Santa Anna Mountain, in Coleman County.

Collectively the summits, escarpments, and plateaus thus composed of the horizontal Edwards limestone represent a wide topographic level which once extended over nearly the entire Coastward Slope, from the mountain front to the eastern edge of the Grand Prairie and Balcones scarp line. This was a plain (the Edwards Cut Plain), and occupied nearly 100,000 square miles of the Texas region. During long periods of degradation, the first of which was in early Tertiary time, prior to the deposition of the Plains formations, the continuity of this level was largely destroyed by erosion, especially in that portion which gently arched over the Central Province, resulting in its almost entire removal from that area, except the remnantal summits mentioned, and the establishment of the two opposing escarpments of the Plateau of the Plains and the Grand Prairie, which have been gradually receding from each other over the Central Province.

By the establishment of a diversified drainage upon and below the ancient Edwards Cut Plain the main area of the Central Province has become a series of benches successively farther and farther below the general level of the former. These plains are classified into two distinct subgroups, those of the western portion and those of the eastern portion of the Central Province, each of which includes several minor groups.

Red Beds plains.—The relief of the western group of plains is that of a series of almost level plains of wide extent bordered by eastward-facing escarpments of erosion and established upon the Red Beds formations (see fig. 34, Sheet IV, Special Illustrations; also fig. 50, Sheet VII, Types of Plains and Scarps). The eastern portion, at least that part south of the Trinity River, consists of less extensive plains which have been more completely broken by deep canyons and are composed of Carboniferous and older Paleozoic rocks. The plains of the western subprovince as above outlined, and of the eastern subprovince north of the Colorado, are mostly dip plains which incline to the west and are bordered on the east by long escarpments (see fig. 66, Sheet X, Types of Rivers and Canyons). These escarpments occur at wide intervals in parallel north-south directions, and are so arranged as to impress the traveler who crosses them from east to west, from plain to plain, with a sensation of constantly ascending a series of steps. The apparent dip of the plains to the west at a very slight angle, in a direction contrary to that of the continental slope, is due to the fact that the region is the eastern limb of an old pre-Cretaceous syncline (the ancestral trough of the plains) which underlies all the Texas region between the Grand Prairie and the Rocky Mountains. This old structure has been re-exposed by denudation of the Tertiary and Cretaceous strata which once covered it.

Palo Pinto Plain.—The eastern third of the Central Province is more rugged and varied in relief. This is due to the harder and more resistant nature of the older Paleozoic formations out of which it is carved and which are successively encountered by the denudation in progressing to lower and lower strata.

North of the Callahan Divide, in what is known as the Palo Pinto country (see fig. 54, Sheet VIII, Types of Plains and Scarps), this relief consists of a cut plain carved out of Carboniferous sandstone, marked by scarps, mesas, and canyons, with occasional valley stretches of "mesquite flats," or level prairie where extensive beds of shale prevail. This character of country also extends a short distance south of the Callahan Divide, where it is called the Brownwood country.

The Burnet country.—Still farther south, adjacent to the drainage basin of the Llano River, the so-called Burnet country is found (see fig. 39, Sheet X, Special Illustrations). This is so very rugged that it is considered mountainous by the inhabitants. It is composed of a series of erosion levels cut below the Edwards Plateau, imposed in succession first upon the Carboniferous and then upon the Silurian and Cambrian strata, and finally cut down to a basement plane of ancient granite and schists, upon which the drainage of the Llano and a section of the Colorado is now established. These various levels of the Burnet country are often extensive features, such as the Backbone Plateau west of Burnet and the Packsaddle Mountains. Notwithstanding its rugosity, this area, which may have been a monadnock—or remnantal hill in a generally planated region—before Cretaceous times, is now a subcircular basin of erosion, below the general level of the Plateau of the Plains and the Grand Prairie, surrounded by overlooking scarps of their strata, which once completely buried it.

Coast Plains.

The coast plains of Texas include the country within the Eastern and Southern provinces, and consists of three broad types of country—the Coast Prairie, the East Texas timber belt, and the Rio Grande embayment.

These plains are a continuation of the Atlantic Coastal Plain of the Eastern and Gulf States, yet are essentially different from that in many features. At the east line of Texas they have the general characters seen in the other Southern States, consisting of a gently sloping surface, extending from a mountainous background (the Ouachita Mountains) to the Gulf, its eastern border attaining an elevation of about 500 feet in southern Arkansas. As it bends to the southwest its features become gradually modified, until they present several notable variations from the Coastal Plain to the east. The most notable differences are the absence of a well-defined interior border between the Ouachita Mountains and the Colorado River, the increasing proportion of prairie, the different adjustment of the fall line of the rivers, and a great embayment which the plain makes up the valley of the Rio Grande, somewhat analogous to that of the Mississippi.

Between the Ouachita Mountains and the Colorado River the Coastal Plain is so continuous with the Regional Coastward Slope, which extends westward to the Rocky Mountains, that its border in this region must be an arbitrarily assumed line practically coinciding with the coastward border of the Black Prairie as far south as the Brazos. South of the Brazos the Balcones scarp gradually develops and makes a well-defined interior limitation of the Coastal Plain toward the Rio Grande.

The Coast Prairie.—The Coast Prairie is a belt of prairie land not over 100 miles wide which borders the Gulf of Mexico in Louisiana and Texas. This is a grass-covered constructional plain, newly reclaimed from the Gulf of Mexico, whose interior margin rises scarcely 100 feet above the sea. It is marked by an exceedingly level surface, hardly broken except by a few low drainage grooves, which become fewer and more faintly developed toward the Rio Grande. Upon it a youthful drainage system is being established, while the seaward extension of the through-flowing streams crosses it. These rivers have wide and deeply indented thalwegs, with gentle, terraced slopes filled with old alluvium.

The floor of the sea border of Texas is a submerged, gently sloping, sandy plain or shelf extending 50 miles seaward. By action of tide, wave, current, and wind this sand is piled into long island strips, which fringe the coast and stand almost at sea level. These are separated from the land by shallow lagoons, in which most of the sediments of the river are deposited. The building of the sand bars by wind and wave and the filling up of the lagoons between them by

river sediments, in connection with gradual uplift, may possibly explain the origin of much of the adjacent Coast Prairie.

East Texas timber belt.—North of the Colorado the Coast Prairie is succeeded on its interior margin by a hilly belt of sandy timber land, corresponding to the outcrop of the Eocene formations. This area is a dissected dip plain.

The substructure is sandy and unconsolidated and is occupied by a greatly branching drainage system, which results in low eminences with gentle slopes and without sharply marked scarp lines, except near the western border, where the dissection of an indurated stratum has produced low summit mesas, such as the Iron Ore Knobs, occurring along a line between Rusk and Gonzales.

Plains of the Southern Province.—The Southern Province includes in its relief the major part of the Coast Prairie, together with the western prolongation of the modified southern continuation of the East Texas timber belt and the Black Prairie up the Rio Grande into the district known as the Rio Grande embayment. Collectively these features represent the southern attenuation of the greater Coastal Plain as modified by the geologic structure of the eastward deflection of the Cordilleran front in northeast Mexico and the increasing westward development of the Balcones escarpment. The influence of increasing aridity upon induration and erosion results in a slight variation in the relief.

In this province the country west of the Coast Prairie, with gradually increasing altitude and more ancient and fully developed drainage systems, becomes more undulating, and finally consists, toward its interior margin, of low, rolling hills, which increase in rugosity toward the Balcones scarp line. These hills are capped by gravel wash from the Edwards Plateau. West of a line from San Antonio to Laredo a low synclinal trough (the Rio Grande embayment), threaded by the Rio Grande, sets in and the slope changes from directly coastward toward the river, forming the north side of a trough between the Balcones and Mexican sierras, which inclose it on the north and south, respectively. The slopes in this district have a normal inclination of less than 8 feet to the mile. The Texas side of the Rio Grande embayment consists of a low broken plain abutting against the sharply defined interior Balcones escarpment of the Plateau of the Plains. Its surface presents a few interesting features of minor relief, including long stretches of level country, several solitary volcanic hills, hills of circumdenudation, and the Anacacho Mountain (see fig. 56, Sheet VIII, Types of Plains and Scarps).

Some plains, as in the vicinity of Spofford and Del Rio, are of constructional origin and present the aspect of gravel-covered flats, analogous to that of the surface of the Llano Estacado; they have been produced by the distribution of arid material by storm-wash deposition.

Rising out of the interior or northern margin of this plain, in Uvalde and Kinney counties, are a number of low dome-shaped volcanic or laccolithic necks or stocks (see fig. 22, Sheet II, Special Illustrations) and monadnocks of horizontal stratification, capped by sills of igneous rock. The Anacacho Mountain, in Kinney County, is an exceptional feature of relief. It is a long cuesta or monoclinal mountain rising out of the plain, presenting a steep escarpment of stratification to the north and sloping toward the Rio Grande.

PLAINS OF THE TRANS-PECOS PROVINCE.

The Trans-Pecos Province, as previously stated, is a combined region of plain and mountain, the total area of which is about equally divided between these two forms of relief. The plains differ from those of the Regional Coastward Slope alike in origin, geologic formation, details of relief, and vegetation. The latter are chiefly the result of the emergence and destructional base-leveling of the coastal slope, unaccompanied by structural deformation. The former are largely structural valleys originated by the deformation which produced the mountains, which have been converted into constructional areas by accumulation of débris from the surrounding highland.

The plains of the Trans-Pecos Province are of two principal types—plateau plains and bolson plains; though, exceptionally, lava plains occur.

PLATEAU PLAINS.

Plateau plains are extensive areas of plain surmounted by a sublevel summit area and bordered more or less completely by escarpments.

The plateau plains of the Trans-Pecos Province are larger benches which border the mountain ranges or rise from the bolson deserts. They consist of wide stretches of sublevel plain, either isolated or projecting benchlike against the bases of the true mountains of deformation and standing above the general level of the Great Plains region on the east and the bolson deserts of the interior. They are cut by deep canyons and bordered by steep cliffs and escarpments. They are stratum plains upheld by thick bands of durable rocks, which form their summit level and the surrounding escarpments. Below this cap rock softer and more friable strata usually occur, making the slopes of the adjacent escarpments (see fig. 24, Sheet II, Special Illustrations; also fig. 35, Sheet IV, Special Illustrations).

These features are genetically more nearly allied to the Cordilleras than to the plains of the Regional Coastward Slope, inasmuch as they represent the platforms of the mountains and owe their present configuration to marginal erosion of the Cordilleran region. They are also genetically related to the features of the Colorado Plateau.

The plateau plains are conspicuous features from northern New Mexico southward to the thirtieth parallel in Texas. The largest area of these plains occurs in northern New Mexico adjacent to the Snowy Range. They also occur south of the Snowy Range (as the Galisteo Divide), and form extensive areas between the eastern Front Ranges and the Oscura chain of sierras in southern New Mexico and Texas north of the thirtieth parallel.

LAS VEGAS PLATEAU.

The plateau plains of northern New Mexico, north of latitude 35° 30′, have previously been collectively designated by the writer the Las Vegas Plateau. This region, as a whole, resolves itself into three great topographic benches or levels, standing one above another, which may be designated, in descending series, the Mesa de Maya, the Ocate, and the Las Vegas plains.

Mesa de Maya.—The most elevated and conspicuous of these plains is known in different places as the Raton Mountains and the Mesa de Maya (see fig. 53, Sheet VIII, Types of Plains and Scarps). It is an elongated dissected plateau extending into the Great Plains, almost due east from the neighborhood of Trinidad, Colorado, to the Texas line. It lies mostly just south of the Colorado line, but sometimes reaches into that State. Fisher Peak, southeast of Trinidad, is a summit on the Mesa de Maya. The summits gradually slope from nearly 10,000 feet above the sea to 5000 feet at the one hundred and third meridian. The steep slopes of these mesas rise nearly 4500 feet above the adjacent regions of Colorado and New Mexico. This dissected plain is a series of remnants of a once extensive plateau, now cut into numerous blocks by the streams which rise along it. The mesa summits are thick beds of ancient lava, while the slopes leading down to the plain are sandstones and shales, with coal beds, of the Upper Cretaceous formations. The beautiful Sierra Grande, a large conical summit standing just east of the one hundred and fourth meridian and south of Folsom in northeast New Mexico, is also an outlier of the Mesa de Maya.

Ocate Mesa.—This mesa flanks the Sangre de Cristo Range from the Spanish Peaks south to Las Vegas. West of Trinidad stands another mesa butte, known as Simpsons Rest. This is a flat-topped bench, but it is 3000 feet lower than the opposing Fisher Peak of the Mesa de Maya plain. Its cap rock, instead of being volcanic material, is a band of thick sandstone. This is the remnant of another and lower-lying mesa plain, extending west to the foothills of the Rocky Mountains near the one hundred and fifth meridian and south from near the Arkansas in Colorado to the Cimarron River of New Mexico. This Cimarron River is an eastward-flowing headwater branch of the Canadian. It is not to be confused with the Cimarron of extreme northeastern New Mexico, which flows eastward through No Mans Land and Oklahoma into the Arkansas.

The southern continuity of this mesa is broken by the Cimarron Valley, but between that stream and the Mora it again expands into a large area known as the Ocate Mesa, from whose broad platform rise the Ocate crater (altitude, 8902 feet) and the igneous necks of the Turkey Mountains. The eastern border of the Ocate Mesa, which is about 7000 feet in altitude, except where interrupted between the Colorado State line and the headwaters of the Canadian to the south, is an escarpment standing nearly 500 feet above a still lower plain, next to be described. Royodo and Gonzales mesas and the Canadian Hills are eastern outliers of this bench.

Las Vegas Mesa.—The Mesa de Maya and the Ocate Mesa plains rise above a still lower and more extensive plain, which may be called the Las Vegas Mesa. This includes the country extending south of the Mesa de Maya and southeast of Trinidad Mesa, to the great cliffs of the Canadian Valley, and east toward the Great Plains nearly to the Texas line. Near its interior border this has an average altitude of about 6000 feet, and it slopes gently to the east. It is a vast, grassy, stratum plain underlain by a thin cap rock of chalky limestone, the Colorado formation. Beneath this cap rock there are thick beds of sandstones which weather into precipitous cliffs, making its borders and canyons (see fig. 61, Sheet X, Types of Rivers and Canyons). Out of the Las Vegas Mesa rise many volcanic craters and dikes, which are elsewhere described.

Between Springer, Las Vegas, and Lamy Junction, along the Santa Fe Railway as it follows the east front of the Rocky Mountains and around the southern end of the southernmost spur of the Rockies, the traveler has unusual facilities to observe this topographic feature.

Galisteo Plateau.—The Las Vegas Mesa continues toward the Rio Grande completely around the southern end of the Sangre de Cristo Range. The Santa Fe Railway follows this portion of the plain, here called the Glorietta Divide, from the east front of the mountains around their southern end to the Rio Grande. To the north the traveler sees the serrated crest and ridges of the mountains, to the south a level plain.

Between the heads of the Gallinas and Galisteo rivers the mesa summit extends almost due south for a hundred miles, from the southern termination of the Sangre de Cristo Mountains to the northern end of the Jicarillas group, forming a narrow flat-topped divide between the waters of the Pecos on the east and those of the Rio Grande (Galisteo Creek) and the Sandoval Bolson on the west. Its level summit region is terminated by sharp escarpments of horizontal sandstone, which lead down on the east to the Pecos Valley and on the west (except along the heads of the Galisteo, which drains into the Rio Grande) to the desert bolsons. As far as the head of the Gallinas this plateau is but a narrow shelf, cut into innumerable table-lands by the headwater drainage of the Pecos. To the south it expands into a wide upland region.

The cliffs which sharply terminate the coastward border of the Las Vegas and Galisteo mesas form one of the longest and most remarkable escarpments in America, extending in a circuitous line from the one hundred and fourth meridian first nearly due west to the one hundred and sixth meridian and then south along the western border of the great Pecos plaza to the north end of the Jicarillas, a distance of nearly 300 miles. These cliffs are in beds of sandstone overhanging the lower-lying Pecos Valley.

Near the latitude of 34° 30′ the Galisteo Plateau divides to the south, around the north end of the Jicarilla Mountains. To the southeast it forms a narrow bench in the northeastern side of the Jicarilla and Fort Stanton ranges, on the side next to Pecos River. The western continuation ramifies into many tonguelike projections between the Pecos and the Rio Grande. The Mesa Jumanes forms the divide of the Sandoval, Jornado, and Franklin bolsons. Between the last it sends southward a tonguelike extension, known as the Chupedero Plateau, the southern end of which grades into the northern end of the Sierra Oscura Range. A branch also extends irregularly west, then southwest toward Socorro, its southern borders forming the northern limits of the Jornado. Another extension of this plateau follows the western side of the Stanton and Sacramento ranges, making a shoulder between them and the Franklin Bolson.

South of the Texas–New Mexico line the plateau country persists, modified in character by change in composition of the rocks and peculiar orogenic movements. It is represented in Texas by the plateau called the Sierra Diablo, elsewhere described in this paper as a mountain form.

BOLSON PLAINS.

The term "bolson," derived from the Spanish word signifying a purse, is an apparently level valley, usually slightly depressed toward the center, and inclosed by mountains, ordinarily without drainage outlet. These plains, or "basins," as they are sometimes called, are largely structural in origin. Bolsons are generally floored with loose, unconsolidated sediments derived from the higher peripheral region. Along the margins of these plains are talus hills and fans of bowlders and other wash deposits brought down by mountain freshets. The sediments of some of the bolsons may be of lacustral origin. The talus hills in Texas are covered with a peculiar growth of yucca, sotol, cactus, and other desert flora. The floor of the bolsons is generally made of finer material, and supports a flora of stunted shrubs and grasses, such as mesquite, greasewood, artemisia, and cactus, usually of different species from those of the adjacent foothills and mountains. A portion of the floor of a bolson plain is well shown in fig. 28, Sheet III, Special Illustrations.

It is essential, in both the geographic and the geologic discussion of this region, to bear in mind the distinction between bolson plains and plateau plains. The plateau plains and the mountains are genetically related, the strata composing the one being bent onto or flexing out into the other. The bolson plains, on the other hand, are newer and later topographic features, consisting of structural valleys between mountains or plateau plains, which have been partially filled with débris derived from the adjacent eminences. The plateau plains are usually destructional stratum plains. The bolson plains are constructional detritus plains filling old structural troughs.

The bolsons are void of surface streams. The few water courses that enter them from the adjacent mountains quickly terminate, owing to the porosity of the soil and to evaporation. They are of that class of streams known as "lost rivers." Some mountain-born rivers, however, like the Rio Grande, cross the bolsons in consequent valleys of their own, cut far below the general level of the bolson plain.

The bolsons of the Trans-Pecos region occur in approximately four longitudinal belts corresponding in their north-south trends to the axial direction of the mountains. The most eastern of these lies along the east front of the Guadalupe and Santiago ranges. The second belt lies between the eastern Front Ranges and the Hueco chain of sierras, and is known as the Howard Bolson of Trans-Pecos Texas. The third is between Hueco and the Sierra Oscura. The fourth lies west of the axis of the Sierra Oscura chain and forms a continuous series of basins north of El Paso, through which the Rio Grande finds its way. This belt is known as the Rio Grande Valley.

BOLSONS OF THE EAST-FRONT BELT.

Along the eastern front of the Trans-Pecos Mountains there is a series of basins that may probably once have been inclosed bolsons, the configuration and history of which have not yet been fully studied. Two of these constitute the feature now popularly known as the Pecos Valley, and are drained by the Pecos River. These are inclosed on the east by the escarpments of the Plateau of the Plains, on the south by the Stockton Plateau, on the west by the eastern Front

Ranges of the Cordilleras, and on the north by the plateaus of north-central New Mexico. They are separated from each other by a narrow constriction produced by an eastward prolongation of the foothill ranges of the Guadalupe Sierra near the Texas–New Mexico line. The larger and more northern of these, which lies almost wholly in New Mexico, may be called the Roswell Basin, and the more southern one, which lies in Texas, the Toyah Basin.

The floor of the Roswell Basin is indented nearly a thousand feet below the level of the Llano Estacado and is veneered with Pleistocene alluvial formations. The Toyah Basin is limited on the south by the steep escarpments of the Stockton and Edwards plateaus, across which the Pecos has found a consequent outlet.

Along the east front of the mountains, between Comanche Mountains and the Pecos, in the vicinity of Marathon, there are incipient bolson plains which have been captured by the headwater drainage of Maravillas and San Francisco creeks.

BOLSONS OF THE INTERIOR RANGES.

Howard (Salt Lake) Bolson.—This is situated between the Davis and Guadalupe sierras on the east and the Vieja and Diablo sierras on the west. It forms a vast inclosed basin extending approximately along the one hundred and fourth meridian almost the entire distance north and south across the Trans-Pecos region of Texas. The lowest depression is at the northern end, near the New Mexico line, where the drainage collects into a series of salt marshes known as Howards Lakes. These lakes have been used for hundreds of years by the Mexican population as a source of supply for salt.

Extending southward from the main area of the bolson, which includes only the country between the New Mexico line and the Texas Pacific Railway, are two arms, known as the Ryan and Eagle flats. The Ryan Flat extends from east of Marfa to west of Chispa. The Eagle Flat lies between the plateau of the Sierra Diablo of the Vieja Sierras and the Eagle Mountains of the Hueco Sierras, and slopes southeast from the foot of Sierra Blanca. This is probably a western continuation of the Ryan Flat. From these flats a narrow outlet at 4000 feet leads northward between the Davis and Diablo mountains into the main body of the Howard Bolson. The highest part of the perimeter of the southern and western ends of the Ryan and Eagle flats has an elevatiou of 4750 feet. Salt Lake represents the lowest depression; its altitude is 3600 feet. The northward slope of the bolson is 1150 feet in a hundred miles, or about 11 feet to the mile.

The more extensive portion of this bolson north of the Texas Pacific is an old destructional valley, eroded out of strata which outcrop on the slopes of the adjacent Guadalupe and Diablo mountains. The highest end of Ryan Flat is at the south, within 50 miles of the Rio Grande, near the north end of the mountains known as the Chinatis. Here the bolson receives the drainage from the great sloping stratum plain known as the Cuesta del Burro, which marks its southern end (see fig. 60, Sheet IX, Types of Plains and Scarps).

Hueco Bolson.—One of the most extensive and characteristic bolsons of the Trans-Pecos region is that lying between the Oscura group on the west and the Hueco and Sacramento chains on the east, in southern New Mexico and extreme western Texas. This vast expanse of level plain extends through two degrees of latitude, from just south of the thirty-fourth parallel southward to the Rio Grande between Fort Hancock and El Paso. It is 40 miles wide at its northern end and broadens to 90 miles at its southern border along the Rio Grande.

On all sides this bolson is inclosed by high mountain blocks or mesas. The mountainous perimeter includes the Sierra Blanca, Hueco, and Sacramento ranges on the east, the Franklin, Organ, and San Andreas blocks on the west, and unnamed Mexican mountains on the south. At its north end is the Mesa Jumanes, dividing it from the Sandoval Bolson. A benchlike mesa projecting from the Sacramento Mountains is also shown on its eastern border.

Although apparently level, this plain slopes southward, according to the profile of the El Paso and Northern Railroad, from 4500 feet at its northern end to 3500 feet at its southern end, having an approximate gradient of 7 feet per mile.

The northern end of this valley or basin presents several peculiar phenomena. Here are extinct volcanic cones from which was extruded a sheet of lava which flowed south 70 miles in a a narrow belt, making the "malpais" country crossed by the highway from Carthage to White Oaks. Near the south end of the "malpais" sheet is a salt marsh covering an oval area of nearly 500 square miles. Southwest of the salt marsh are the celebrated white sands. These sands are loose grains of gypsum. Still southward the soil is a slightly reddish or brown sandy loam, superficially resembling the soils of the Great Plains region, but largely derived from old lacustral or fluviatile deposits which here make the floor of the basin. Around the margins of the bolson are many benches, consisting of fan-shaped heaps of talus derived from the mountains, deposited by torrential streams.

The Rio Grande crosses the southern and lower end of the bolson in a valley of its own, cut far below the surface level of its desert plain. This valley of the Rio Grande is incised some 200 feet below the level of the bolson plain at El Paso and nearly 500 feet south of Fabian station. The eroded edge of the bolson plain forms a scarp line marking the outer edge of the river valley. The valley slope, weathered into typical bad lands, consists of alternations of stratified bands of clays, waterworn gravel, sand, and pebble, forming the substructure of the bolson. By the percolation of calcareous waters and the precipitation of a limy matrix (tepetate) these beds have been consolidated in places into the formation known to the Mexicans as the Tierra Blanca.

Sandoval Bolson.—The disposition of the drainage indicates that in the region of the Antonio Sandoval grant, about 100 miles due south of Santa Fe, there is another true bolson or inclosed basin, which represents a northern continuation of the great structural depression of the Hueco Bolson. This basin is apparently surrounded on the north by the Galisteo Mesa; on the east it adjoins the south-extending tongue of the Glorietta Mesa and its continuation known as the Pedernal Hills, forming the drainage divide between the Pecos and this bolson; on the south it is overlooked by the steep summits of the Mesa Jumanes; while the Sandia and Manzana ranges border it on the west. Into this bolson drains an area about 40 miles in its greatest length and 30 miles wide.

In the center of this apparent bolson are many small lakes and cienagas, all forming a single basin. They are known as the Laguna del Perro, the Alkali Ponds, the Chico Pond, etc. The lowest depression of this bolson has an altitude of approximately 5000 feet. The topography of its northern limits can be made out from the Lamy and San Pedro topographic sheets of the United States Geological Survey.

Bolsons of the Rio Grande Valley.—The Rio Grande, from its entrance to the San Luis Valley in southern Colorado to where it cuts the Sierra del Carmen Mountain, in longitude 103°, just east of the apex of the great bend, flows almost continuously through a chain of ancient bolson plains connected by canyons which progressively increase in length and depth toward the southeast. As stated by Dr. G. G. Parry in the report of the Mexican Boundary Survey, "The general course of the river represents a continuous series, in descending steps, of basins, more or less extensive, then a cañon, forming, as we may say, the *spout* of the basin, which, again, opens on a basin of lower level." This simple statement embodies the great principle of formation that characterizes all this district, and gives to its topography a significance at once clear and instructive.

That portion of the stream north of El Paso follows the axial directions of the bolsons; east of the latter place the river crosses their trends.

The bolsons of northern New Mexico north of the Santa Fe Railway are not within the region which forms the subject of this paper. From Bernalillo south the river follows three conspicuous bolsons. The most northern of these lies between Bernalillo and Socorro, being bounded on the east and south by the Sandia Range. South of Socorro, to Fort Selden, is the bolson of Jornado del Muerto. The third extends from the Dona Ana Hills to near El Paso, and may be termed the Mesilla Bolson. The present valley of the river is established below the level of the bolson plains, whose bisected remnants stand several hundred feet above it, as benches between the rivers and the mountains.

Jornado del Muerto Bolson.—The Jornado del Muerto Bolson is perhaps the most noted of the bolson plains of the Rio Grande Valley. Its name, signifying the journey of death, was given because of the great difficulty travelers found in crossing its waterless waste. The Jornado occupies most of the country south of Socorro and north of the Dona Ana Hills at Rincon. On the east its limits are at the San Andreas and Oscura sierras; on the west, Los Caballos and Fra Cristobal sierras. The Rio Grande has cut and follows a valley averaging 400 feet below the level of its floor. The Atchison, Topeka and Santa Fe Railway continues upon it from south of Mesilla to Lava station.

The surface formation consists of detritus of rock in all respects the same as that composing the neighboring mountains from which it was doubtless mainly derived. The precise thickness of this deposit could not be very accurately determined, as only a few natural sections were observed, and these near the base of the mountains. In two localities it was observed by Dr. G. G. Shumard to have a thickness of nearly 500 feet.

Mesilla Bolson.—The southern end of the Jornado Bolson is terminated by a group of stratified and volcanic hills which extend west from the Organs via Dona Ana and Fort Selden to the Rio Grande. This separates the Jornado del Muerto from the Mesilla Bolson, which begins south of this barrier and extends a hundred miles toward El Paso. On the east this bolson is bounded by the Organ Mountains; on the west, by a group of low mountains and hills extending south from the Sierra Magdalen. South of the Southern Pacific, between Afton and Aden, several volcanic craters rise from the plains, sending long lava sheets to the southeast. The towns of Mesilla and Las Cruces, two of the most flourishing places in southern New Mexico, are situated in the Rio Grande Valley within the bolson, and around them extensive agriculture is carried on by irrigation.

The bolsons of the Rio Grande below El Paso can not here be described in detail.

THE DRAINAGE.

The extensive region under discussion has a diverse drainage, its streams varying in origin, number, length, and volume with the topographic and structural conditions, rainfall, evaporation, slope, and porosity of the surface. Some parts have numerous streamways which drain the surface and lead the water to the sea. Others, like the great bolson deserts of the Trans-Pecos region and the Plateau of the Plains, are practically without superficial drainage, and the surface precipitation is disposed of by evaporation and structural imbibition.

There is little superficial obstruction to the direct run-off of precipitation, whereby a constant supply of water to streamways may be regulated, except such as the forest growth of the Eastern Province, and the absorbent character of the dry soil and rocks in certain local areas — for example, in the Cross Timbers, the Llano Estacado, and the bolson deserts of the west. The Central Province and the Trans-Pecos Mountains are largely without either floral or structural obstruction to run-off, and hence they are rapidly drained after rainfall.

TYPES OF STREAMS.

Some streamways, like those draining the Coast Prairie, are of a simple consequent type; they rise upon a slightly tilted plain and occupy one geographic province. Others of a similar character traverse two or more provinces, being prior relative to one and consequent relative to the other (see figs. 38 and 42, Sheet V, Special Illustrations). Still others are of a more complicated nature and origin and traverse all the provinces.

In the eastern portion of the State, owing to the large rainfall, streamways are numerous and continuously carry flowing water, while non-copious streams which enter this region from the west also become copious within it through locally acquired laterals. Only in this and the Coastal Plain is navigation practicable, rapidity of fall and scarcity of water prohibiting it to the west.

In parts of the State, such as the summit of the Llano Estacado and the great bolson deserts of the Trans-Pecos Province, drainage channels of local origin are few in proportion to area, feebly etched, and normally without water except for a few hours after heavy rainfall. These areas consist of extensive plains of gentle slope underlain by pervious substructure, and the streamways are the products of the torrential rainfall, which is sporadic and less in quantity than the average rate of evaporation. In such runways as are developed water is normally absent, its presence being dependent on floods, which are infrequent. Furthermore, the temporary run-off is seldom of sufficient quantity to endure more than a few miles, owing to loss by imbibition in its normally dry and porous stream bed and by evaporation. Hence the water does not persist far enough to form outlets to the sea.

Streams of a third type are frequent in the Central Province and around the interior margin of the Southern Province, which derive their normal run-off from springs draining the substructure of the plateau (structurally impeded drainage). These streams, which are usually vigorous at their head, are often interrupted in their lower courses, presenting irregular alternate sections of dry and watered channels, the water disappearing by absorption in sands, gravel, or fissures and reappearing at other places (see fig. 64, Sheet X, Types of Rivers and Canyons). They may be called spring rivers, and are of two general types: the first, those which rise in the margins of the Llano Estacado and Edwards Plateau and receive their water from gravity springs; the second, those which originate in great fissure springs that rise through hydrostatic pressure, like those of the Balcones scarp line (see fig. 37, Sheet V, Special Illustrations).

Drainways of a fourth type may be called through-flowing rivers; they derive their water from the snow-covered ranges of the Rocky Mountains of northern New Mexico and Colorado and traverse all the geographic provinces. These streams receive their principal volume from the Cordilleras, and their courses across the Regional Coastward Slope are practically great antecedent canals passing across the Greater Texas region without serious lateral reinforcement. Such streams are the Canadian, the Pecos, and the Rio Grande (see figs. 62 and 63, Sheet X, Types of Rivers and Canyons).

DIRECTION OF FLOW.

Most of the streams normally follow the continental slope toward the sea across the various provinces and are of the kind called consequent streams. Others, which are exceptional, flow at right angles to that of the normal regional slope, following parting valleys (see South Bosque River in fig. 65, Sheet X, Types of Rivers and Canyons) The Pecos west of the Plateau of the Plains is the most conspicuous type of the latter class. The Clear Fork of the Brazos, Hubbard Creek, and Jim Ned Creek, of the Central Province, and certain forks of the Trinity in the East-Central Province, are minor examples. The Rio Grande in portions of its course through the Trans-Pecos Mountains and the Rio Grande Plain follows great structural troughs.

Still another class of streams consists of headwater ramifications (caletas) of the longitudinal streams which drain the inland-facing scarps. These are called obsequent streams. They are usually short obsequent headwaters, and flow in a

direction the reverse of that of the consequent streams, which follow the continental slope. They are found along the north-south scarp lines of the Central and East-Central provinces and along the western breaks of the Llano Estacado.

Some streams are composed entirely of one of these types, and may be called simple in character. Others present in different portions of their course several of the types described, and may be called compound.

The topography of each stream valley varies in its course with the structure of the country upon which it is established. Hence the members of a series of long parallel streams flowing across different belts of country locally resemble one another in each belt.

The character of the run-off in the streamways in the Texas region is of three kinds—intermittent, interrupted, and continuous. Intermittent run-off is sporadic in character; it occurs only after rainfall and soon ceases. Most of the drainways of the western half of the State are of this character. Drainways of this type are termed arroyos, and are indicated by dotted blue lines upon the map. Interrupted drainage is that in which the continuity of the permanent flowing stream is broken by alternate stretches of dry streamway. Rivers of this character abound in the East-Central and Central provinces and are indicated by alternations of continuous lines and dots (see Nueces River on map). Continuous streams are those which flow continuously from the head of permanent water to their mouths, and are shown on the map by unbroken blue lines.

CLASSIFICATION OF THE DRAINAGE.

While some of the larger streams flow across all the different types of country and are prior thereto, each of the greater provinces we have mentioned has a distinct group of local rivers, forming a drainage system, which finds outlet directly to the sea or is gathered into the larger lateral trunks. The different members of each system possess similar characteristics of origin, slope, length, and valley topography.

When a streamway gathers its drainage from one province it is of a provincial type. On the other hand, when it flows through two or more provinces, diverting a number of local drainage systems, it becomes composite. The rivers of the Coast Prairie system are of the simple type; those of the Central Province are composite.

Geographically the drainage of the Greater Texas region as a whole may be classified generically as follows: rivers of the Cordilleras, rivers of the Great Plains, rivers of the Central Province, rivers of the East-Central Province, rivers of the Edwards Plateau, and rivers of the Coastal Plain.

RIVERS OF THE CORDILLERAS.

The rivers of the Cordilleras are the Arkansas, Canadian, Pecos, and Rio Grande. They receive most of their volume from the precipitation on the Colorado group of the Rocky Mountains, and gather little or no drainage from the provinces of the Texas region as they cross it. They are normally flooded in May and June, at the time of snow melting in the mountains at their headwaters.

Canadian River.—The Canadian is a through-flowing stream which crosses the Panhandle of Texas in the direction of the slope of the plains through a deep, wide valley scored below the plains level (see fig. 42, Sheet V, Special Illustrations). This stream is interrupted in character in that portion of its course extending through the eastern margin of the Great Plains. The gradient of this valley is less than that of the plain, and hence the valley decreases in depth downstream. Like all rivers cutting across the plains, its channel is normally a wide bed of wet sand threaded by diminutive streams. With the exception of one or two small creeks in its own valley, it receives little or no drainage from the Coastward Slope plain. Probably at one stage of its early history the Upper Canadian, which is consequent in its relations as it emerges from the mountains, flowed into the Pecos, and was diverted across the Llano Estacado at a later period by headwater capture of its present eastward portion, which is antecedent and which was originally a river of the plains.

Pecos River.—The Pecos is a continuous through-flowing stream, and, like the Canadian, is consequent in its upper portion, rising in the Snowy Range of New Mexico, but the history of its lower course (see fig. 35, Sheet IV, and fig. 40, Sheet V, Special Illustrations) is more complex. Its middle course takes a different direction to the sea, however, flowing southward in a longitudinal direction in the wide antecedent parting valley established between the inward-facing escarpment of the Llano Estacado and the Cordilleran front as far as the thirty-second parallel in Texas, where it bends southeast, first through a wide bolson valley (the Toyah Basin) and then into a narrow consequent canyon across the Edwards Plateau to its junction with the Rio Grande. About midway between its head and mouth this river is reinforced by a number of small streams from the Guadalupe Mountains of New Mexico. Elsewhere it receives no waters from the country it traverses. It is probable that this stream once terminated in the Toyah Bolson, from which it subsequently found an outlet across the Edwards Plateau by capture of the Lower Pecos (or that portion now flowing through the limestone canyon), which was an independent stream — a headwater of the Lower Rio Grande — of the type of the Nueces and other spring rivers of the plateau margin. It is also probable that the Lower Pecos, together with a portion of the Rio Grande below the mouth of the Pecos, constitutes a drainage system to which the Upper Rio Grande west of the mountains has since been annexed by capture.

Rio Grande.—The Rio Grande is nearly 1500 miles in length and forms the southern boundary of Texas for 1000 miles. Perhaps no other river presents as many different characters as does this stream in its many parts from source to mouth, or is of more complex type. It is a through-flowing composite stream which has its source in southern Colorado on the interior side of the Rocky Mountain front. From the latter State southward through New Mexico to the Quitman Mountains of Trans-Pecos Texas, more than 500 miles, its course is established in consequent channels indenting the surface levels of a chain of sandy bolson deserts, separated by low mountains, across whose solid substructure the river cuts through short canyons, such as the pass from which El Paso takes its name (see fig. 7).

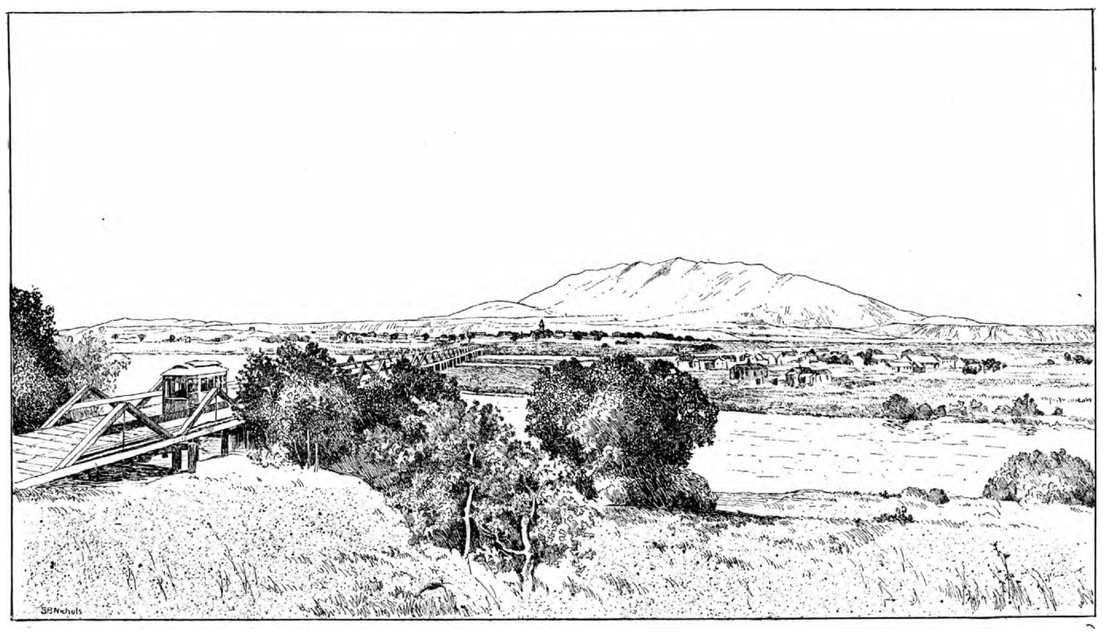

Fig. 7.—Valley of the Rio Grande, El Paso, Texas, showing passage of the river from the Mesilla Bolson to the Hueco Bolson, across the south end of the Franklin Range and terraced mesas of the dissected bolsons.

Between El Paso and Del Rio the river passes out of the bolson region and onto the Coastward Slope plains, across the eastern ranges of the North American Cordilleras. This passage follows steep and impassable canyons for 300 miles across the mountain trends between Presidio and the mouth of San Francisco Creek, first southwest, then northeast. Below the mouth of San Francisco Creek it enters the Stockton Plateau, and crosses it by another steep canyon cut in limestones. It follows this in an eastward direction for 125 miles, to near Del Rio, where it enters the low synclinal trough of the Rio Grande embayment, which parallels the trend of the Cordilleras in this region. In this portion of its course and thence to the sea its valley is a shallow indentation in the Coastal Plain. Below Ringgold, where the trough of the Rio Grande Plain has flattened out into the Coastal Plain, it crosses the latter in an eastward direction and is navigable for 100 miles. This river, as a whole, represents a complicated geologic history, including the union into its present course of what were originally several streams. Its flow is continuous from its source to about the thirty-fifth parallel, in New Mexico; thence to Presidio, Texas, the flow is interrupted in character. At Presidio the flow becomes continuous by the accession of the waters of the Conchas River of Chihuahua. This flow is augmented by numerous hot springs as the river passes through the mountains, and by the Pecos River.

RIVERS OF THE PLAINS.

There are no true rivers of the plains in the general region under discussion. The few faint drainways that exist upon the plains consist of draws, ordinarily without water, leading into the shallow basinlike depressions or head canyons of the streams of the Central and Southern provinces. It is a misnomer to call these streams true rivers, for their courses are so shallow they are hardly traceable, seldom contain water, and never present a continuous flow. In time of rainfall they form wide, shallow, slothful, turbid floods, which serve only to distribute the loose débris of the surface to a slightly lower level. To this class belong certain long draws, such as the Paloduro, Tule, and Castro creeks, leading into the canyon of Red River; the Catfish and Amarillo, leading into the Brazos; and Sulphur and similar drainways leading into the Colorado. It is true that these draws are literally the headwater drains of the rivers of the Central Province, and that these streams, which were inherited in past geologic time from the Plateau of the Plains, when it extended far eastward of its present border over the western part of the Central Province, were once rivers of the plains, but it is here preferable to treat them as rivers of the Central Province. The Llano, Guadalupe, Frio, Nueces, and Devil rivers, which are principally established upon the Coastal Plain, have similar headwater draws passing back upon the Edwards Plateau.

RIVERS OF THE CENTRAL PROVINCE.

The rivers of the Central Province are the Cimarron, North Canadian, Washita, Red, Brazos, and Colorado, with large and important tributaries, including the North Fork, South Fork, Pease, and Wichita, belonging to the Red River, the Salt and Double Mountain forks, belonging to the Brazos, and the North Fork, Concho, and Llano, belonging to the Colorado. The constant portions of these streams rise along the eastern margin of the plains, either in the front scarps or in the deep canyons which incise them, like Red River. Normally these are continuous streams (interrupted in some instances) of small volume deriving a constant head-water supply from the structural drainage of the Plateau of the Plains through the medium of numerous gravity springs. In months of maximum rainfall they become excessively flooded with red sediment, which is carried to the lower countries (see fig. 21, Sheet II, and fig. 38, Sheet V, Special Illustrations). They are long continuous slope streams, which have their principal and widely branching ramifications developed in the Central Province, and which gather little or no local drainage as they pass the lower-lying provinces.

The gradients of these streams across the Central Province become greatly flattened near their sources, and are farther below the general summit levels of the regional slope than any others in Texas. In fact, Red River cuts nearly 900 feet below the level of the Plateau of the Plains before it emerges from them. The Colorado, from the Plateau of the Plains to the East-Central Province, is cut 500 feet below the regional summit as preserved in the Callahan Divide. Such facts indicate the great antiquity of these streams relative to the age of some other systems to be described. These streamways were originally established upon the older and higher plateau level, and by inheritance have approximately maintained their original locations as they cut deeper and deeper into the floor of unconsolidated Red Beds and Paleozoic rocks. The upper waters of such of these streams as cross the gypsum beds of the western part of the Central Province are often brackish. In the lower portions of their courses, through the East-Central, Eastern, and Coastal provinces, these valleys are marked by wide bottoms, rising in several terraces, which are veneered with old alluvium derived from prehistoric denudation of the Central Province.

RIVERS OF THE EAST-CENTRAL PROVINCE.

Still another category of streams is composed of rivers which rise upon and drain the prairies of the East-Central Province. The through-flowing rivers of the Central Province cross the East-Central Province through grooves deeply indented below the general level of the flat upland plains of which the latter is composed. Upon the upland plains intervening between the older streams has been developed the newer system which comprises the rivers of the East-Central Province. These include the Trinity group, between the Brazos and Red rivers, and the Paluxy, Leon, and San Gabriel groups, between the Brazos and the Colorado. The many ramifying branches of the Trinity gather all the drainage north of the Colorado, even taking it from the very margins of the valleys of the greater through-flowing Central streams, and carry the water, through the Eastern Province, directly to the sea. The branches of the Paluxy, Bosque, Leon, and San Gabriel similarly drain the upland portion of the Grand Prairie between the Brazos and the Colorado, but deliver their water to the Brazos at the edge of the Eastern Province. These are simple consequent slope streams, and are usually interrupted in character, the water sometimes running in deep pools and then disappearing in dry, stony channels. They all rise close to the western margin of the Grand Prairie plain, but by rapid descent of their streamways soon become so deeply indented that their paths are much lower than the surface of the upland prairies. Their permanent water is largely derived from the structural drainage of the sands of the Cretaceous beds. Some of them, like the Leon and San Gabriel systems, are also largely reinforced as they cross the Balcones fault zone at the border of the Grand and Black prairies, by springs rising under hydrostatic pressure through fissures.

RIVERS OF THE EDWARDS PLATEAU.

The rivers which rise within the edge of the Edwards Plateau somewhat resemble both the rivers of the plains and those of the East-Central Province, and yet present variations sufficient to justify their consideration in a special category. These streams, such as the Blanco, San Marcos, Guadaloupe, Medina, Frio (see fig. 23, Sheet II, Special Illustrations), Nueces, and Devil rivers, which pass from the Plateau Province directly

across the Balcones scarp line into the Coastal Plain, are complex, presenting entirely distinct topographic characters in the two provinces. On the plateau summit their ultimate heads are gentle, waterless draws, like those of the Llano Estacado. These lead suddenly down into the deep, wide-bottomed box canyons indenting the margin of the plateau, also similar to those of the eastern border of the Llano Estacado, and at the bottom of which water begins to flow from gravity springs. The permanently flowing water of these canyons makes streams of great beauty. The headwater streams continue only short distances, and are succeeded by waterless gravel. On passing the Balcones scarp line into the lower-lying country of the Rio Grande embayment the character of the stream-way entirely changes. Here the beds are only slightly indented below the general level of the country and have no steep canyon walls. Furthermore, in this portion of their courses some of them, like the Frio and Nueces, except in time of flood, are normally dry gravel beds without water. Lower down in their courses, however, permanent water again appears.

RIVERS OF THE SOUTHERN AND EASTERN PROVINCES.

Within the Southern and Eastern provinces, which collectively make the Coastal Plain, two distinct systems of streams have originated and occupy the relatively higher surfaces between the through-flowing streams. The longest and oldest rivers of these systems rise along the eastern margin of the Black Prairie and at the Balcones scarp line; those of the second begin at the western margin of the Coast Prairie, upon which they are established. To the first class belong the Sabine, Sulphur, Neches, and Angelina. The second includes a number of short streams (creeks and bayous) which in their coastal extent are sluggish and brackish. In that portion of the Coastal Plain south of the Colorado there are streams of another category, which have their origin in remarkable fissure springs that break out at the foot of the Balcones escarpment. Among these spring rivers may be mentioned the San Marcos, Comal, San Antonio, Las Moras, and San Pedro.

RÉSUMÉ OF THE DRAINAGE SYSTEM.

In résumé it may be said that the rivers of the mountains are complex composite streams which can be fully explained only in a geologic treatise. The rivers of the Coastward Slope plains consist of four distinct systems of consequent streams which have developed during different epochs of geologic history, each recording distinct changes of level, accompanied by a migration back and forth of the coast line.

By provinces, it may be said that the drainage of the Trans-Pecos country is of a nascent type, being practically nil on the bolson plains. This is partially due to lack of slope, but chiefly to meteorologic and structural conditions, the evaporation and absorption being so much in excess of the rainfall that there is not sufficient run-off to develop streams on these desert plains. The minor drainage of the mountains is also faintly developed in comparison with that of other regions, owing to the lack of sufficient rainfall. The through-flowing rivers of this region (the Rio Grande) gather no local drainage from it.

On the Great Plains, also, the drainage is undeveloped, and for the same reason as in the case of the bolson deserts. Its summit run-off is deficient in quantity and of the flood-sheet type, which tends to destroy rather than to establish surface drainways. The real drainage of this province is underground. Such water as is not evaporated sinks through the superficial strata until it is retarded by the impervious embed of older rocks, upon which it flows laterally by percolation to the incised marginal scarps, where it furnishes the headwater gravity spring drainage of the Central Province.

The drainage of the Central Province is mature or old, its headwaters having etched away the surface upon which it was established, down to lower and lower levels, until it is now superimposed upon the lower-lying Paleozoic beds. This drainage has been inherited.

The drainage of the East-Central Province is adolescent, having passed its period of youthful development. It has not yet completely occupied all the areas of the plain upon which it is established, except along the eastern margin of the region. Those portions of the streams of the Central Province which continue into the East-Central Province are inherited and revived in the latter portion of their course, having been at base-level or estuarine here when the sea bathed the eastern border of the East-Central Province and when the latter was a newly made coastal plain. The older drainage system of the East-Central Province is adolescent, but younger. The newer drainage of the Coastal Plain is in its youth, and illustrates most completely the development of simple drainage upon a newly reclaimed and gently tilted coastal plain.

The sediments of all these streams testify to the work which they perform in lowering the general surface level. The Rio Grande in New Mexico, flowing through the unconsolidated and heterogeneous formations of the ancient bolsons, is notorious for its dull-yellow sediments and silt. On the other hand, all the streams draining the Red beds of the Central Province are famous for their vermilion floods. Other streams rising in the chalky and argillaceous Cretaceous rocks of the Edwards Plateau and Grand Prairie have a whitish color. The Colorado before reaching Austin receives tributaries from both the Cretaceous and the Red Beds areas, and hence in the lower portion of its course its floods are known as "red rises" and "white rises," those coming from the Llano and San Saba tributaries being of the latter color, while those from the northern laterals are of the former.

These stream valleys, as a whole, record a remarkable geologic history from the close of Cretaceous time to the present, which can not yet be fully interpreted.

CLIMATIC FEATURES.

The region, as a whole, presents extreme climatic variations, especially in humidity, evaporation, and precipitation, which have been important factors in the physiographic and economic conditions. There is every transition from excessive humidity in the forest-clad Eastern Province to maximum aridity in the great deserts of the far west, and from subtropical conditions near

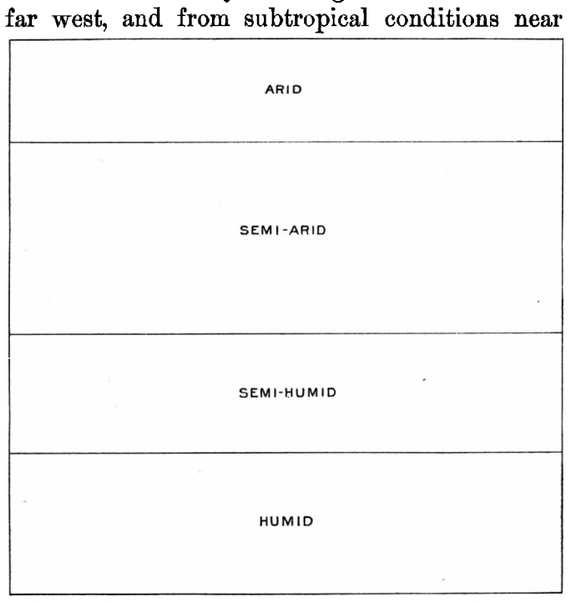

Fig. 8.—Relative areas of humid and arid lands of Texas.

the mouth of the Rio Grande in the northern portion of the Mexican Tierra Caliente, where frost is seldom known, to the north temperate conditions of the Great Plains found in the Panhandle region (see fig. 8). The amount of humidity decreases rapidly from the coast to the eastern front of the Trans-Pecos Mountains, being 9.4 grains per cubic foot of atmosphere at Brownsville in July and 5.1 grains at Fort Davis.

Evaporation, likewise, which has an important bearing upon the physical processes influencing the geography, increases rapidly westward from the coast toward the mountain front, from 45 inches per annum at Texarkana to 82 inches at El Paso (see fig. 16, Sheet I, Special Illustrations).

TYPES OF RAINFALL.

The precipitation of the State is mostly rainfall, although one or more extensive snow storms occur annually in the Panhandle region. These snow storms usually change into rain before reaching the southern Rio Grande. Snow rarely extends south of Austin. The total precipitation (rainfall and melted snow) varies greatly not only in quantity in different regions of the State, but also in time of occurrence. The annual quantity decreases to the westward from 57 inches in East Texas, at Clarksville, to less than 10 inches at El Paso. Between these extreme types of wet and dry conditions there is every transition (see fig. 17, Sheet I, Special Illustrations).

In the humid region of the State the annual precipitation is always sufficient to moisten (saturate) the entire superficies, to saturate the substructure so that the line of rock water is almost coincident with the surface, and to furnish a constant supply of run-off to the entire system of runways—headwater branches, secondary laterals, principal laterals, and rivers. Surface evaporation is retarded by the vegetal mantle, and the surface is more constantly dampened by the greater average humidity. High winds are not constant, and geologic processes (desiccation, erosion, and transportation) are rendered less efficient by the superficial protection of the more cohesive soil and by vegetation.

In the less humid portions of the State the conditions are reversed. The rainfall is always local (spotty) and is never sufficient to moisten the superficies of any extensive area at any one time. It is insufficient to saturate the substructure, so that the line of rock water (increasing in depth unevenly with the decreasing rainfall) is usually not reached on the western border of the plains and in the bolson deserts for a considerable distance beneath the superficies; and it is not sufficient in quantity to supply or develop a system of runways, except on steep slopes, and hence there are extensive areas without visible surface drainage. Evaporation is facilitated (1) by the normally higher temperature of the superficies; (2) by the absence of protective layers of vegetation; (3) by the absence of humid conditions in the atmosphere; and (4) by high winds, which constantly prevail. The prevailing high winds dry the surface, render it pulverulent through extraction of the cohesive moisture, and, by their transportative powers, redistribute the material thus made available.

In general the rainfall decreases in annual quantity from the northeast to the southwest, and belongs to two major types, the Gulf and the Sonoran, each of which presents two well-defined subtypes (see fig. 15, Sheet I, Special Illustrations).

The Gulf type of rainfall is derived from the moisture-laden trade winds which sweep westerly across the Atlantic, precipitating their moisture upon the West Indian Islands and the Gulf periphery of Central and North America.

The Gulf type presents two distinct subtypes, each characterized by having its maximum and minimum falls in different months of the year and by great differences in relative quantity. These subtypes are as follows: The Louisiana subtype of the Eastern Province—the same as that which characterizes Arkansas, northern Louisiana, and the eastern Coastal Plain of the United States—in general has abundant fall for agriculture in all months of the year, but the greatest in winter and spring, the maximum in April and May. The area of distribution of this subtype of rainfall extends into the East-Central, Central, and Southern provinces in diminishing quantity. The Great Plains subtype of the Panhandle (the Trans-Mississippian or Omaha type of Greely) is characterized by having over one-sixth of its annual precipitation in May and June and only one-fiftieth in January. The influence of this type of rainfall reaches over the East-Central Province and extends almost to the Rio Grande.

The Yuma subtype prevails in the Trans-Pecos Province. This is one of general aridity, marked by abnormal maximum rainfall in August (see fig. 9, p. 12). As has been shown by Greely, its moisture is derived from the Pacific by way of Lower California and southern Arizona.

The East-Mexican subtype, which is characteristic of the Southern Province, especially the coast region, is marked by a maximum fall during September—the so-called rainy season of eastern Mexico—and a minimum in April (see fig. 10, p. 12). This type of rainfall extends interiorward across all of southern Texas, following up the Rio Grande Valley as far as the eastern front of the Trans-Pecos Mountains, and its diminishing influence is felt over the Central and East-Central provinces almost to Red River.

The marginal Yuma and Gulf types of rainfall overlap each other in the Central and East-Central provinces, so that in these provinces there are usually two epochs of maximum rainfall, in May and September, respectively, and sometimes a third in June. This combination of overlapping conditions in the provinces mentioned, and the accompanying meteorologic phenomena, produce peculiar climatic conditions productive of erratic floods, which have an important bearing on the agricultural interests and have no doubt been a factor in the peculiar erosion of the denuded Central Province.

The following table gives the quantity and type of rainfall in each of the greater provinces. The figures are compiled from the reports of the United States Weather Bureau, and each station represents a series of years of observation.

TEMPERATURE.

The temperature of the State is also varied. According to Greely, the annual average for various places differs more than 20°; or, to state the case comparatively, in average yearly temperature the valley of the Lower Rio Grande differs as much from the northwestern portion of the Panhandle as does New Orleans from Chicago, or Jacksonville from Boston. The highest yearly

Examples of typical precipitation in the greater provinces of the Texas region.

[Maximum monthly fall indicated by black-face type; minimum falls, by italics.]

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Annual.	Average.
Gulf rains:														
Louisiana subtype:														
Clarksville	5.1	5.4	5.0	**6.9**	**6.8**	5.3	5.1	*2.2*	3.7	3.1	3.5	5.1	57.1	...
Palestine	4.4	3.5	4.0	**4.6**	**5.8**	4.2	2.6	*2.7*	3.2	3.2	4.4	3.8	46.4	14
Great Plains subtype:														
Fort Elliott	*0.6*	*0.5*	*0.6*	2.6	**4.4**	**3.2**	2.3	3.3	1.8	2.5	*0.6*	*0.7*	23.1	11
Abilene	*0.9*	1.4	1.2	2.7	**3.6**	**3.3**	1.7	2.6	2.4	2.3	1.4	1.5	25.0	10
Fort Griffin	*0.9*	1.4	1.2	2.7	**3.3**	**3.8**	2.7	1.1	2.7	2.0	1.6	2.1	24.0	12
Mount Blanco	*0.8*	1 0	0.4	2.1	**1.5**	**2.2**	2.2	2.2	1.6	1.8	0.8	*0.6*	16.4	10
Sonoran (Pacific) rains:														
Yuma subtype:														
El Paso	0.4	0.5	0.3	0.1	0.3	0.5	1.6	**1.9**	1.6	0.8	0.5	0.4	8.9	36
East-Mexican subtype:														
Brownsville	*1.4*	*1.5*	*1.2*	*0.7*	2.1	1.9	3.1	2.9	**5.6**	3.6	1.7	*1.2*	25.9	30
Indianola	2.3	1.9	2.6	*1.3*	3.3	2.6	2.3	3.9	**7.0**	3.7	3.1	3.1	38.7	14
Galveston	3.6	3.0	*2.9*	*2.3*	3.7	4.9	2.1	5.3	**6.0**	4.2	4.3	3.9	47.7	26
Combination types:														
Louisiana-Mexican:														
Austin	*2.2*	*2.4*	2.5	3.0	**4.2**	2.7	*1.8*	2.7	**4.2**	2.7	2.7	*2.3*	33.4	38
Fort Clark	*0.8*	*1.0*	*1.1*	1.5	**3.2**	2.5	*1.6*	2.5	**3.6**	1.8	*1.2*	1.8	22.6	29
Louisiana-Mexican and Great Plains:														
Denison	2.09	3.4	*2.5*	3.9	**4.6**	**4.9**	**5.0**	3.2	**3.8**	3.7	3.13	*2.3*	42.7	...
Decatur	1.9	2.6	*1.5*	3.0	**4.4**	3.8	**4.9**	2.5	**4.9**	1.6	2.5	*1.6*	35.4	...
San Angelo	*0.9*	1.1	1.0	1.7	**3.4**	2.5	**3.1**	2.8	**3.0**	1.8	1.1	1.4	23.7	17

averages (73.9°) are along the Lower Rio Grande; the lowest two are in the Panhandle (55.6°) and at Fort Davis in the Trans-Pecos Mountains (61.2°).

In summer the daylight temperature is very equable for the whole State, but in the western and Trans-Pecos regions there is a fall of about

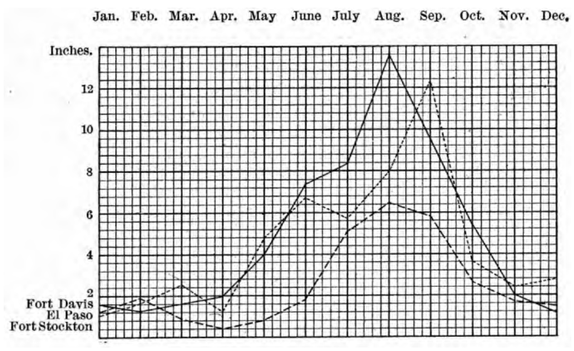

Fig. 9.—Monthly rainfall at points in Trans-Pecos Texas. Pacific (Sonoran) type.

25°, more or less, at night. In the Eastern and Southern provinces the nightly fall is usually less than 7°.

In winter the normal temperature varies from that of Kansas in the Panhandle, the only place in which freezing days of mean temperature occur, to subtropical temperature in the Southern Province, where freezes occur only in exceptional years. No part of the State is free from occasional frosts. The equilibrium of the winter temperature for the whole State, however, is occasionally lowered by cold waves, or "northers," accompanied by violent north winds. These are indrafts of air

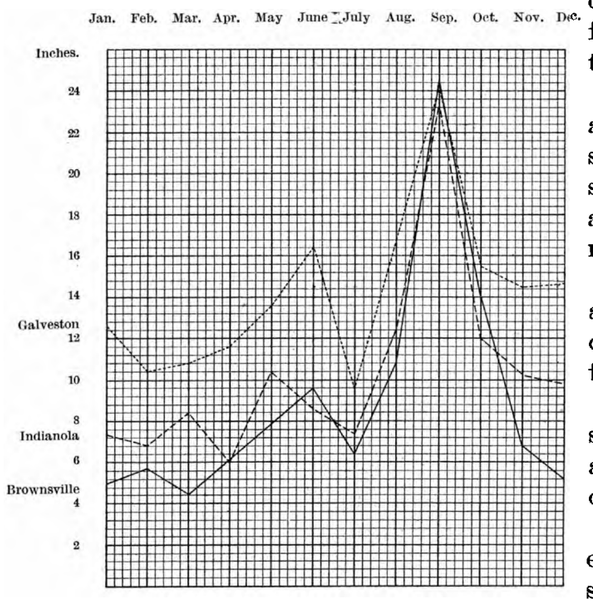

Fig. 10.—Monthly rainfall at points in southern Texas. Pacific (Mexican) type.

following spirally incurving currents of low-area storm centers. The "northers" are the southern extension of the cold waves which radiate from the Northwestern plains over all the United States to the east and south. Parts of the State, as Trans-Pecos and northeast Texas, are very rarely affected by them, not more than twice a year, and over fully one-third the State the "norther" is so light that its coming is usually hailed with satisfaction as a tonic, purifying the air and stimulating personal activity.

VEGETATION.

The State presents a great diversity of flora. Some areas are densely forested; others are vast, treeless plains; others are stretches of prairie with occasional trees; while still others are covered with low shrubs. The forests follow the structural features of very definite belts of country and are locally modified by climatic variations (see fig. 18, Sheet I, Special Illustrations).

The sandy soil of the Eastern Province is occupied by the southwestern extension of the Atlantic timber belt, with its heavy forests of pines, oaks, hickory, ash, liquidambar, etc. This, in itself, presents many local variations, modified especially as it contracts toward the Colorado, finally pointing out near the Rio Grande. Ribbons of this timber belt, decreasing in number of species, extend up the broad alluvial river bottoms into and across the East-Central Province until they reach the outcrops of certain sandy strata, which they follow north and south in two narrow upland belts, and hence are called the Cross Timbers. Outliers of the Atlantic timber belt are also found in the canyons of the Edwards Plateau.

In the Trans-Pecos Province the Rocky Mountain trees are found on the summits and in the canyons of the higher mountains, such as the Guadalupe, Davis, and Chisos groups. This flora is characterized chiefly by the edible pines and the Rocky Mountain junipers and the maguey plants. The trees are also found in the canyons, slopes, and breaks of the Plateau of the Plains, on its eastern and southern borders.

In the Southern Province another flora occurs, which extends into the State from the Tierra Caliente or coastal plains of Mexico. This is the shrubby growth locally known as "chaparral," consisting of low, thorny trees and shrubs, such as the huisache, the mesquite, the Mexican persimmon, the guaxillo, Koebelinea, the large nopal or edible cactus (Opuntia), and other plants peculiarly adapted to this environment.

Around the borders of the Rio Grande Plain, in the stony talus of the Mexican and Trans-Pecos cordilleras, and in the limestone hills of the Balcones scarp line is the yucca belt, wherein are found the sotol, agave, lecheguilla, cactus, and thick-skinned cryptogamous forms.

The bolsons of the Trans-Pecos Province are also largely covered by a flora of low, thorny shrubs peculiar to the deserts of northern Mexico, situated inland of the east front of the Cordilleras, and grading into a yuccaceous flora in the surrounding foothills.

The Great Plains flora—grasses and small annuals (largely Compositæ) on the uplands and cottonwoods in the low streamways—also extends far south into Texas from the northwest.

The Central and East-Central provinces possess a diversified indigenous flora of grasses, annuals, and occasional trees, as well as many species of the adjacent provinces which overlap them.

The coastal and interior borders of the Southern Province are also characterized by the extension into them of the epiphytic zone of the tropical region.

ECONOMIC FEATURES.

The economic features of Texas are as varied as its physical geography, consisting chiefly of a great diversity of agricultural and pastoral soils; most of the ordinary nonmetallic substances used in construction and in the arts; and coal, oil, asphaltum, clays, sulphur, and forest products. Granites, sandstones, limestones, and marbles also occur. It possesses, in unknown quantities, iron, manganese, gold, silver, cinnabar, and copper.

SOILS.

Soils are due to the surface decay of the rocks. When in place, where they originated, they are called *residual* soils; after removal from the place of origin they are called *transported* soils.

The soils of that portion of the State possessing sufficient rainfall for agriculture are mostly residual products of the underlying geologic formations, and are of several distinct kinds, each of which is a monotype, having an excess or a deficiency of some particular mineral ingredient or a distinctive mechanical character, such as the sandy lands of East Texas and the Cross Timbers, the black calcareous clay soils of the Black Prairie, and the red clay soils of the western portion of the Central Province. In most of the State, with the exception of the Trans-Pecos Mountains, the Edwards Plateau, and the Palo Pinto and Llano countries, these soils are deep and without a rocky foundation. Their fertility is usually great. In addition to these classes the Coast and Fayette prairies, as well as the Llano Estacado, Spofford Plain, and the bolson of Trans-Pecos Texas, comprise vast sheets of soil which, although residual in a broader sense, are composed of material so recently transported from some nearby regions, of whose characteristics they partake, that they are more of the nature of transported than of residual soils.

All the through-flowing rivers have wide alluvial bottoms covered with rich transported soils derived from their upper courses and made up of a mixture of the monotypic kinds. Those portions of the State unadapted to agriculture, owing to aridity or shallowness of soil, are devoted to the pastoral interests and produce large flocks of sheep and herds of cattle and horses.

MINERAL RESOURCES.

The mining industries of the State have been as yet but little developed. Iron ore of different classes occurs in the Eastern, Central, and Trans-Pecos provinces. Gold has been found in the Llano, Uvalde, and Trans-Pecos countries. Cinnabar and silver also occur in the latter.

Bituminous coals are found in three distinct fields. Those of Carboniferous age occur along the eastern half of the Central Province and are extensively mined. Cretaceous coals are developed on the Rio Grande. Coal fields of uncertain value have been reported west of the Pecos. Lignite occurs in vast quantities in the Eastern and Southern provinces. Oil is procured near the towns of Corsicana (derived from the Upper Cretaceous formations) and Sour Lake. Asphaltum is mined in Uvalde County. The general occurrence of these minerals is shown in fig. 19, Sheet I, Special Illustrations.

The Grand Prairie and Edwards Plateau contian excellent white and cream-colored limestones and shell marbles, like those of France and Portugal. The Central Province supplies granites, hard limestones, marble, serpentine, and red sandstones of excellent quality and great variety. Building stone is not abundant in the Eastern and Southern provinces or on the Llano Estacado. Materials for making Portland cement especially abound in the Black Prairie and Grand Prairie countries. Gypsum of great purity occurs in vast quantity in the East-Central Province and in Pecos Valley. Clays of many kinds occur. Kaolin, plastic clay, Cornwall stone, and flint, for use in the fictile arts, are found in places, and good brick clays abound.

Salt is found in the western part of the Central Province as extensive strata in the Permian formations; and in the Trans-Pecos region there are incrustations on lakes and in lagoons along the sea coast. It is also obtained as brine in the Eastern Province. Vast beds of ocher, or mineral paint, occur in the western part of the Central Province. Marls, infusorial earth, soapstone, glass, sands, and other undeveloped products are also present. Sulphur is found in the Toyah Basin.

Mineral waters of diverse character, many of them resembling those of the European spas, are found in the artesian wells of the East-Central and Southern provinces, as well as potable waters of great purity.

DISTRIBUTION OF POPULATION.

The population of the State is engaged chiefly in agricultural, pastoral, transportation, and mercantile pursuits. The white race dominates numerically, and is chiefly American in composition, although there is a large foreign element, Germanic and Slavonic, settled principally in the Southern Province. The black race is represented in considerable proportion in the eastern and coastal portions of the Southern Province, but is almost absent from the rest of the State, especially in the Central, Trans-Pecos, and western part of the Southern provinces, where the Indian, locally called Mexican, is secondarily conspicuous. The urban population is found in several large cities, of less than 50,000 inhabitants, the chief of which are San Antonio, Galveston, and Houston, in the Southern Province, and Dallas and Fort Worth in the East-Central Province.

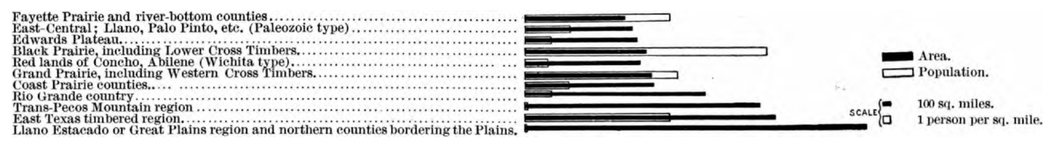

Fig. 11.—Distribution of population relative to area, by provinces.

It is not the purpose of this paper to enter into details of social or vital statistics, especially in view of the fact that a new census will soon be taken, but the manner in which the distribution of the rural population has adapted itself to the geographic features is shown in the accompanying table and in figs. 11 and 20 (Sheet I, Special Illustrations), which are based on the results of the census of 1890.

Distribution of rural population relative to the geographic provinces (census of 1890).

Province.	Subdivision.	Area in square miles.	Rural population.	Rural population to each square mile.
Eastern Province	East Texas timber belt	32,870	623,666	19.00
Southern Province	Coast Prairie[1]	16,960	79,108	4.50
	Fayette Prairie and river-bottom counties	12,105	229,970	19.00
	Rio Grande Plain[2]	23,610	81,151	3.50
East-Central Province	Black Prairie, including Lower Cross Timbers[3]	15,198	481,281	31.60
	Grand Prairie, including Upper Cross Timbers[4]	15,921	300,242	20.00
Central Province	Abilene, Concho, and Wichita countries	15,094	58,848	3.00
Plateau Province	Llano Estacado	44,760	9,299	.15
	Edwards Plateau	14,760	52,180	3.50
Trans-Pecos Province[5]		30,880	9,140	.30

[1] Not counting population of Houston and Galveston.
[2] Not counting population of Dallas and Austin.
[3] Not counting population of Fort Worth.
[4] Not counting population of San Antonio.
[5] Not counting population of El Paso.

ROBERT T. HILL,
Geologist.

April, 1900.

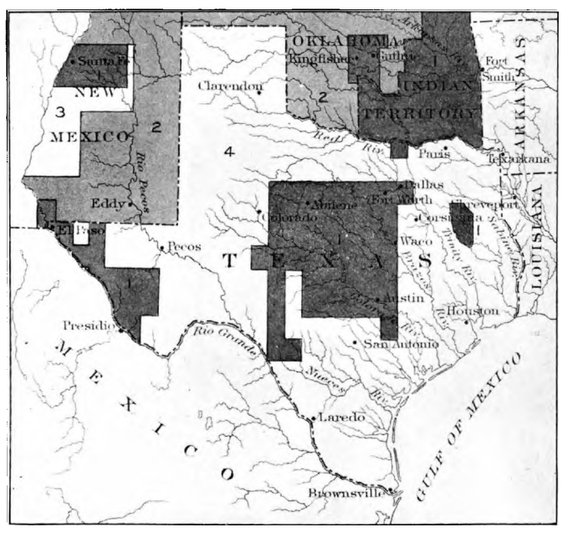

FIG. 12.—MAP SHOWING SURVEYED AREAS OF THE TEXAS REGION.

1, Area surveyed in detail by U. S. Geological Survey, 2, area covered by U. S. Land Office surveys; 3, area reconnoitered by Wheeler survey, 4, not surveyed.

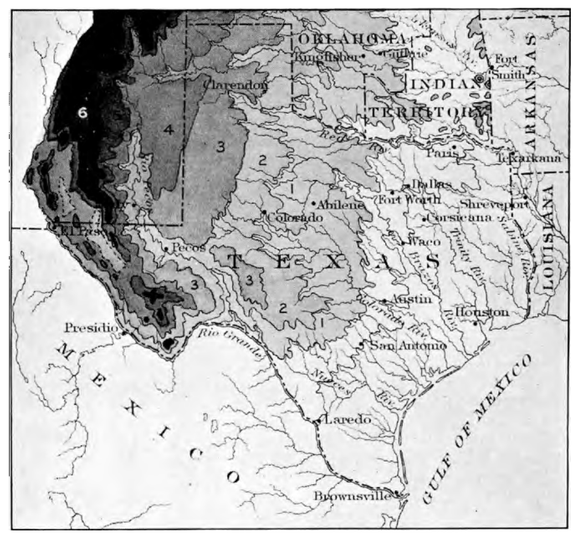

FIG. 13.—HYPSOMETRY OF THE TEXAS REGION.

1, 1000–2000 feet, 2, 2000–3000 feet; 3, 3000–4000 feet, 4, 4000–5000 feet, 5, 5000–6000 feet; 6, 6000 feet or over.

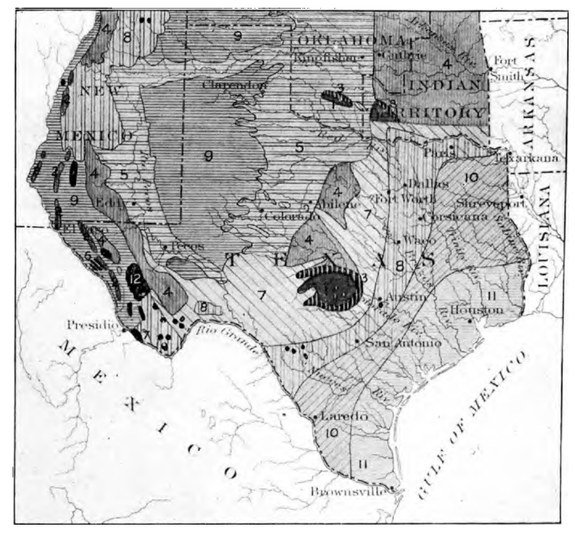

FIG. 14.—GEOLOGICAL MAP OF THE TEXAS REGION.

1, Older granites, 2, Paleozoic and Mesozoic; 3, Cambrian and Silurian; 4, Carboniferous; 5, Permian, 6, Jurassic, 7, Lower Cretaceous, 8, Upper Cretaceous, 9, nonmarine Tertiary, 10, marine Eocene; 11, coast Neocene, 12, later igneous.

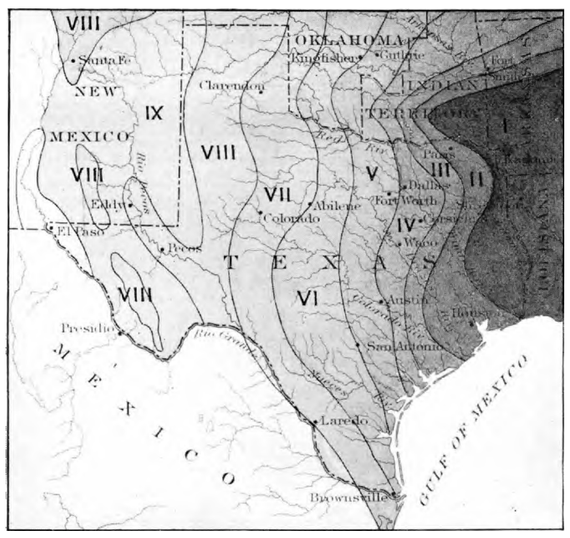

FIG. 15.—PRECIPITATION IN THE TEXAS REGION.

I, Over 50 inches; II, over 45 inches; III, over 40 inches, IV, over 35 inches; V, over 30 inches, VI, over 25 inches, VII, over 20 inches; VIII, over 15 inches, IX, over 10 inches.

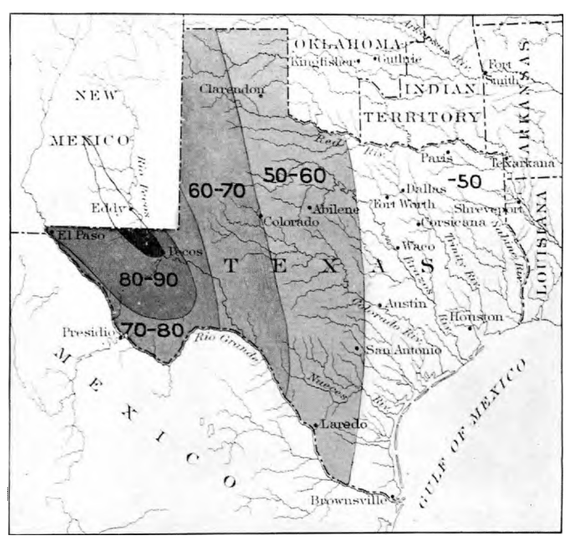

FIG. 16.—EVAPORATION IN THE TEXAS REGION.

In inches per annum.

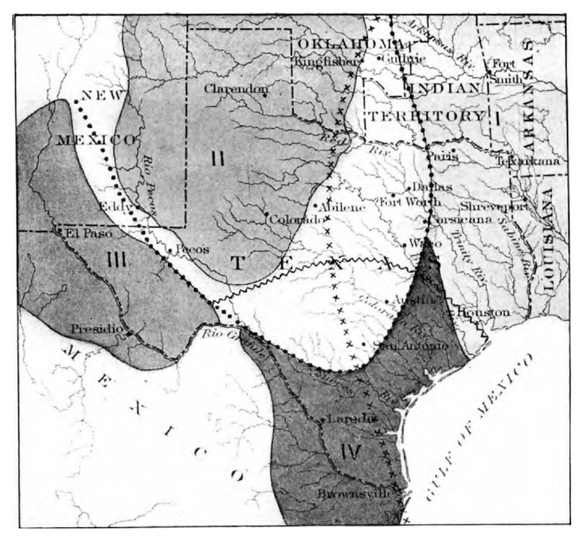

FIG. 17.—TYPES OF RAINFALL IN THE TEXAS REGION.

Eastern (Atlantic) types: I, Gulf type, II, Great Plains type. Western (Pacific) types: III, Yuma type, IV, Mexican type. xxx, Western margin of Gulf type; . . . , southern margin of Great Plains type, ~~~, northern margin of Mexican type.

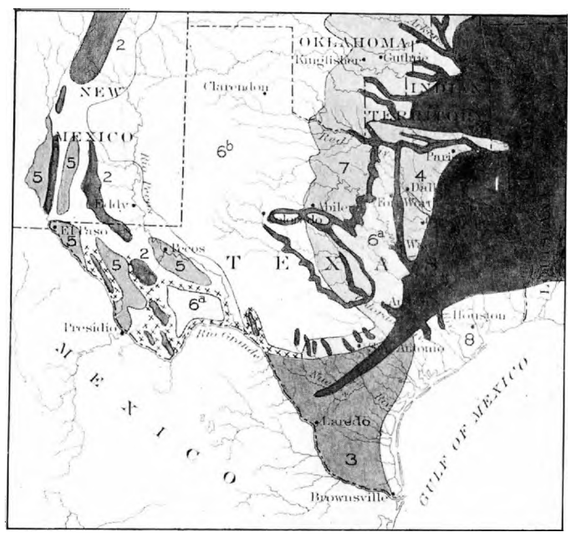

FIG. 18.—FLORAL FEATURES OF THE TEXAS REGION.

1, Atlantic forest belt; 2, Rocky Mountain forest; 3, chaparral; 4, Black Prairie; 5, bolson desert flora; 6a, Grand Prairie, 6b, Great Plains; 7, transitional, with plains, prairie, and Atlantic flora; 8, coast prairies; xxx, yucca belts.

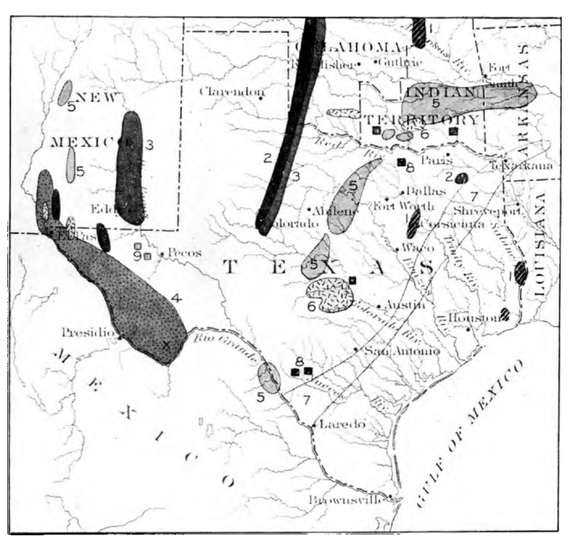

FIG. 19.—MINERAL RESOURCES OF THE TEXAS REGION.

1, Oil; 2, salt; 3, gypsum, 4, precious metals, 5, coal; 6, granite; 7, lignite, 8, asphaltum, 9, sulphur; x, cinnabar.

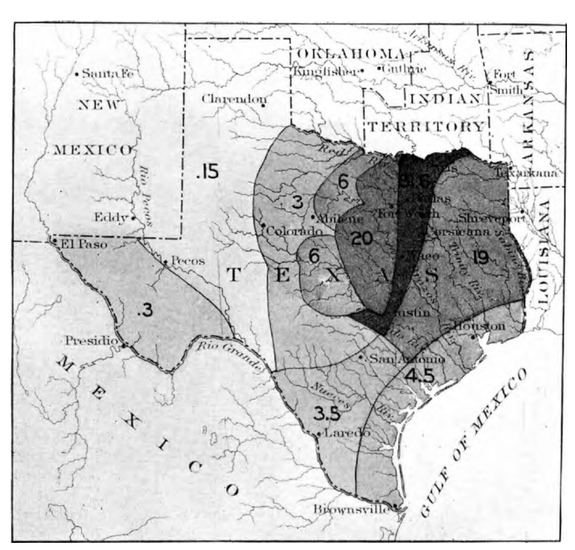

FIG. 20.—DISTRIBUTION OF RURAL POPULATION PER SQUARE MILE, BY GEOGRAPHIC PROVINCES.

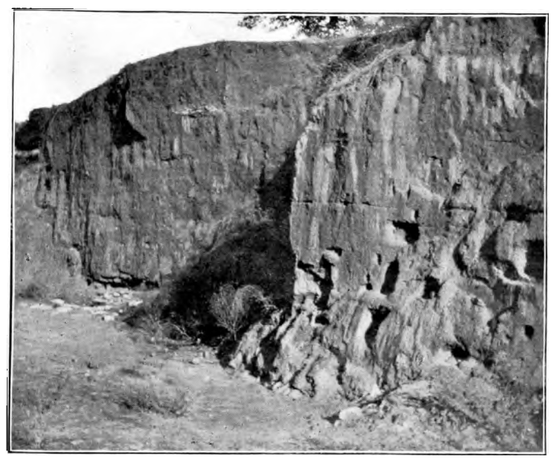

FIG. 21.—OLD ALLUVIUM OF BRAZOS RIVER NEAR GRANBURY, TEXAS.

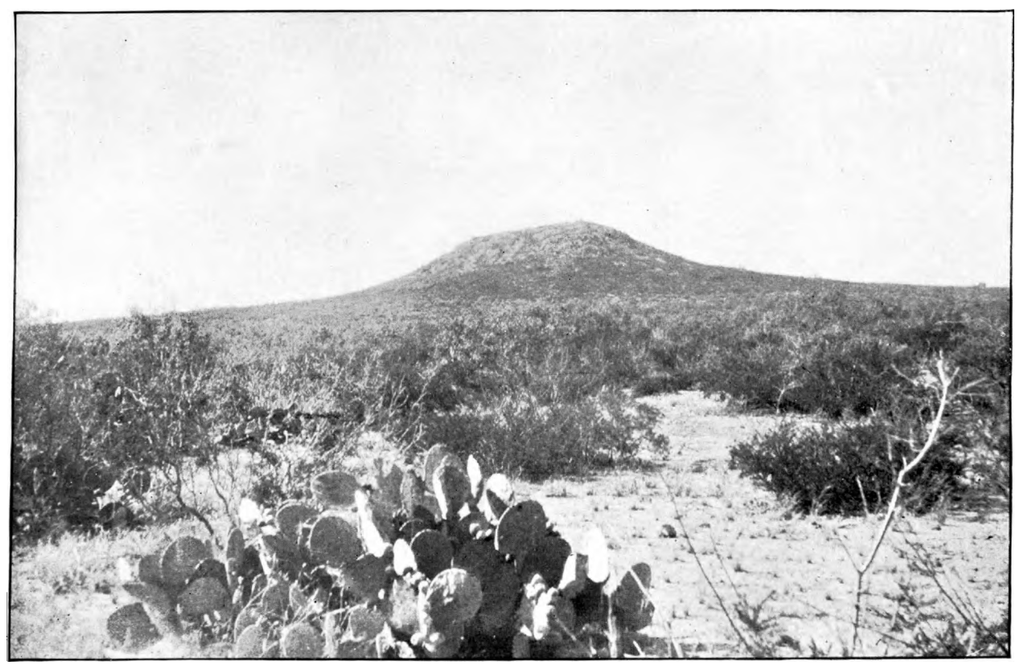

FIG. 22.—VOLCANIC NECK, RIO GRANDE PLAIN.

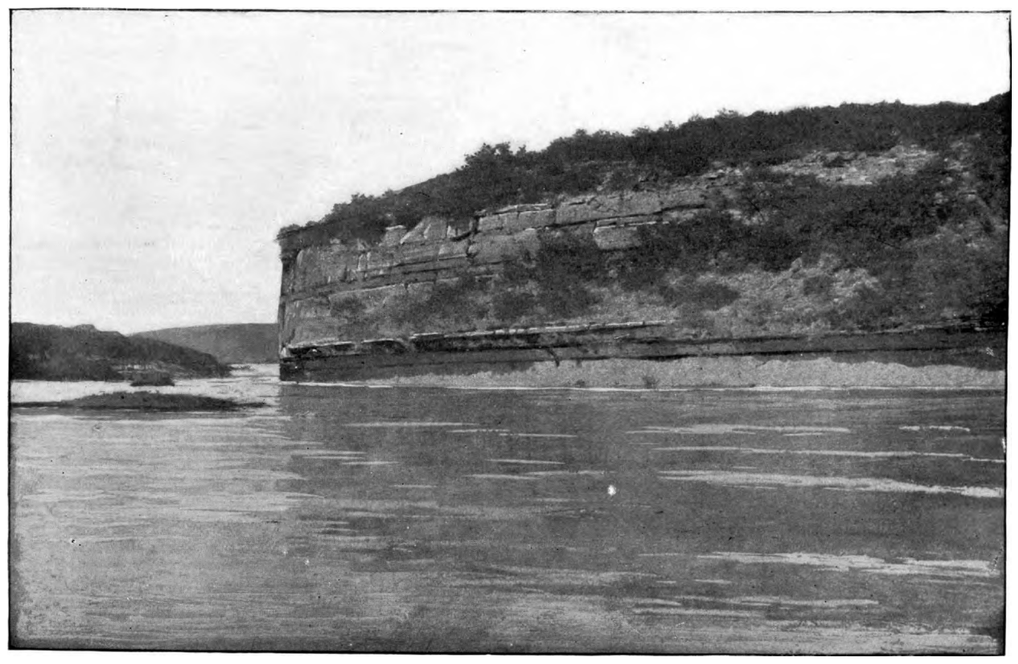

FIG. 23.—CANYON OF THE RIO FRIO, EDWARDS PLATEAU.

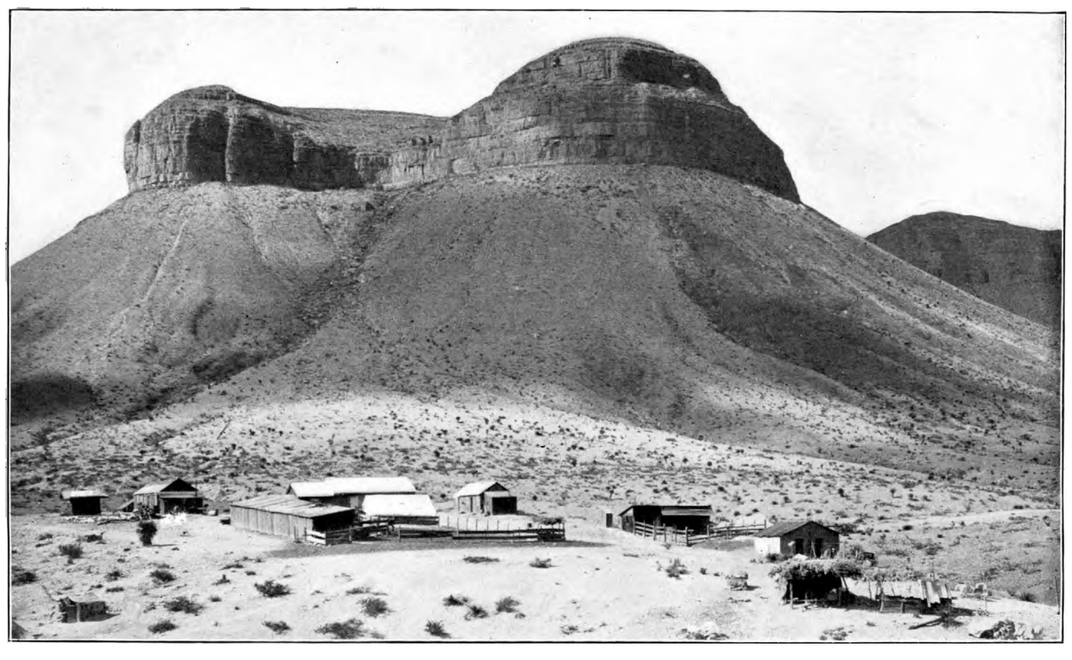

FIG. 24.—OUTLIER OF THE DIABLO PLATEAU NORTH OF ALAMORE, TEXAS.

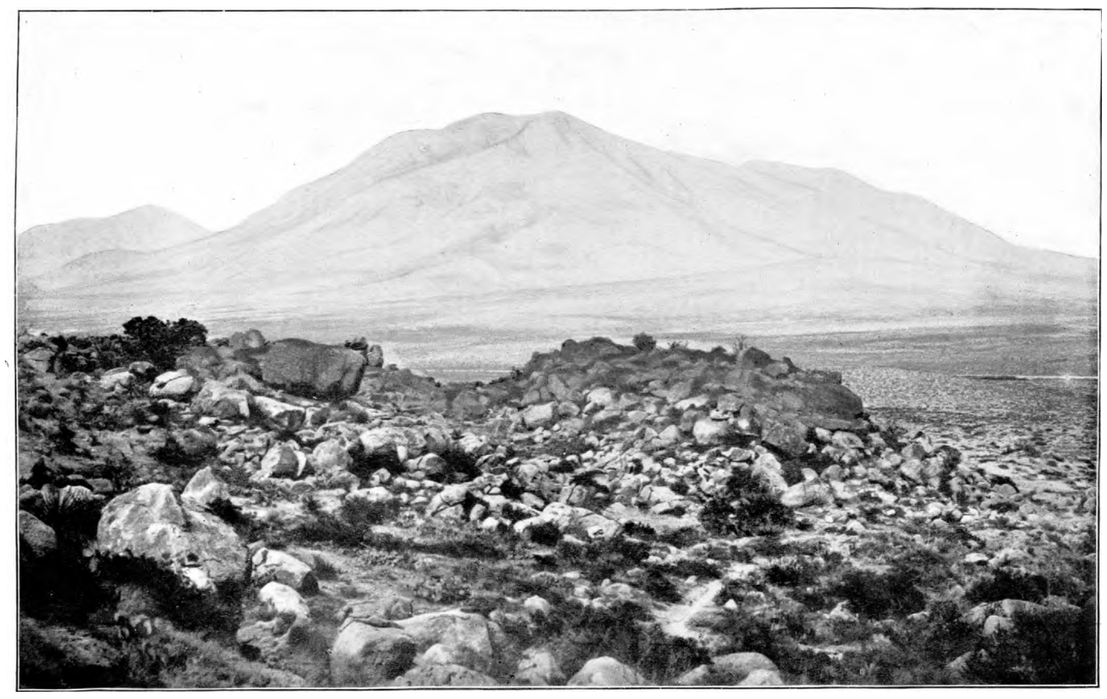

FIG. 25.—SIERRA BLANCA, TEXAS; AN ISOLATED MOUNTAIN OF QUARTZ-PORPHYRY OF THE FORM CALLED A SANDIA.

FIG. 26.—THE EASTERN BREAKS OF THE PLAINS AND ANTELOPE BUTTE, AN OUTLIER OF THE PLAINS.

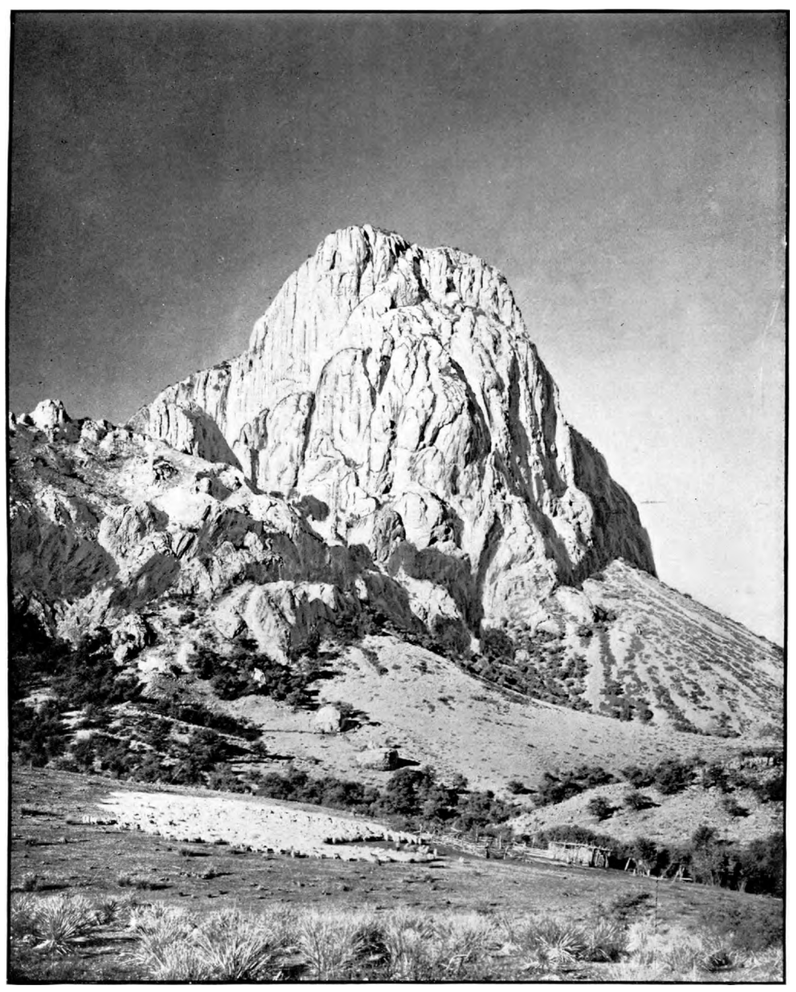

FIG. 27.—NORTH PEAK OF CHISOS MOUNTAINS, BREWSTER COUNTY TEXAS.

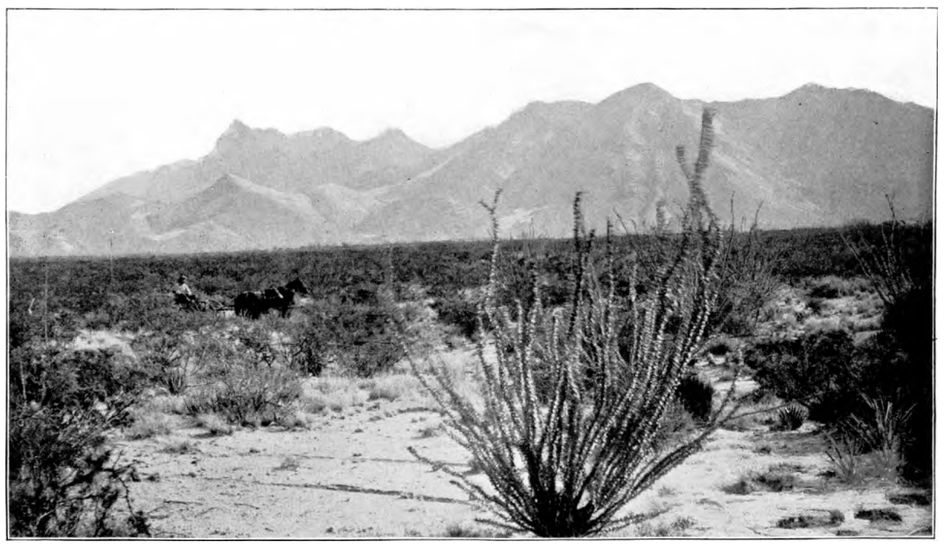

FIG. 28.—QUITMAN MOUNTAINS AND DESERT BASIN SOUTHWEST OF SIERRA BLANCA, TEXAS.

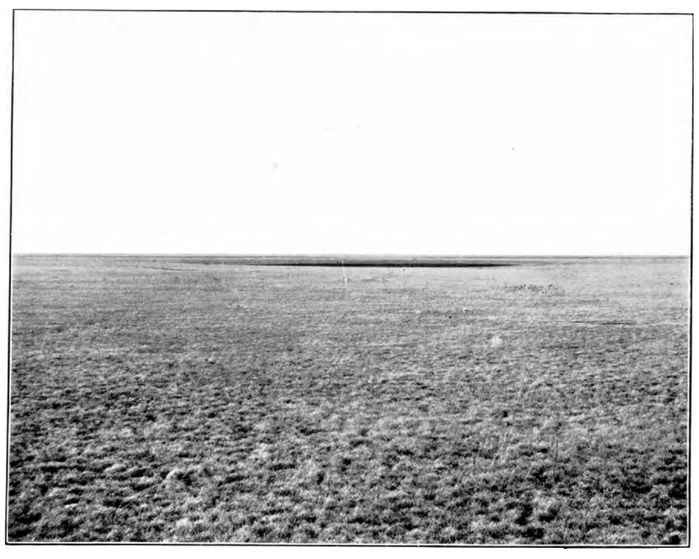

FIG. 29.—SUMMIT OF THE LLANO ESTACADO.

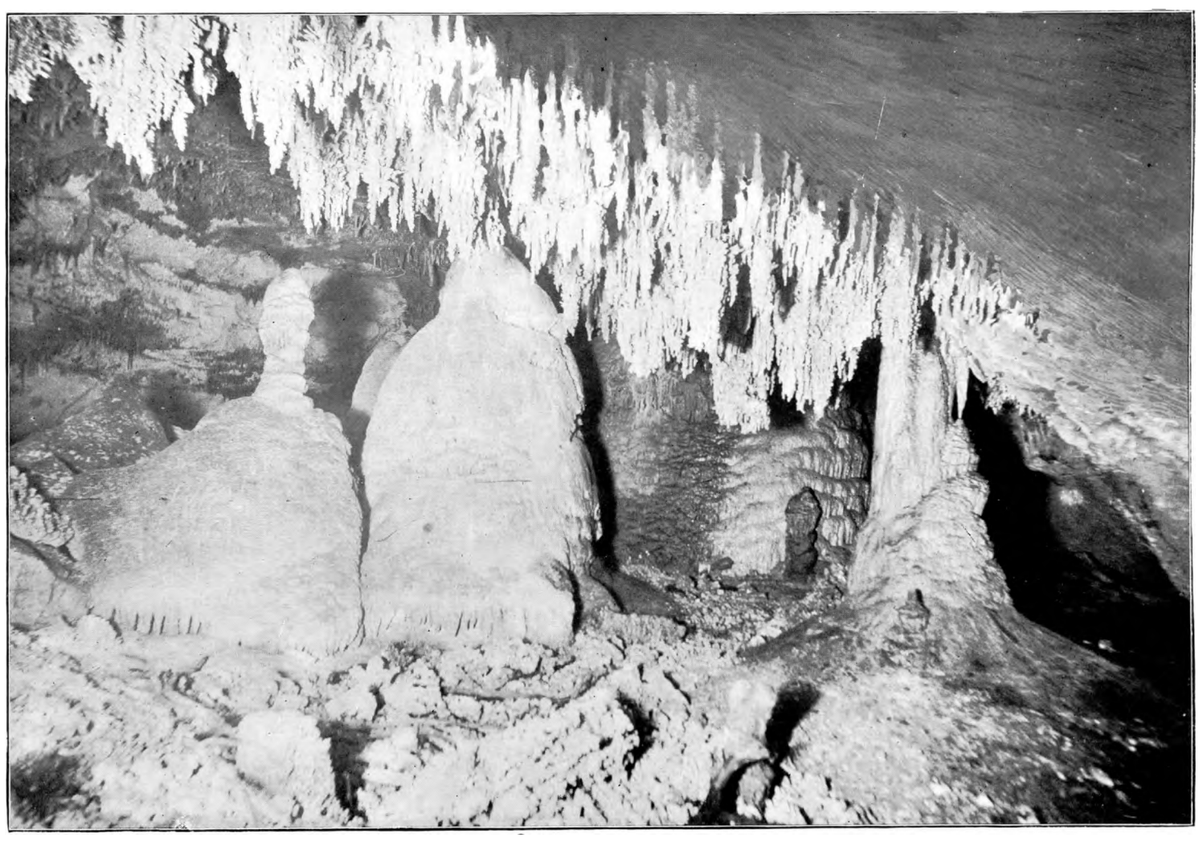

FIG. 30.—HILLCOAT CAVE, EDWARDS COUNTY, TEXAS.

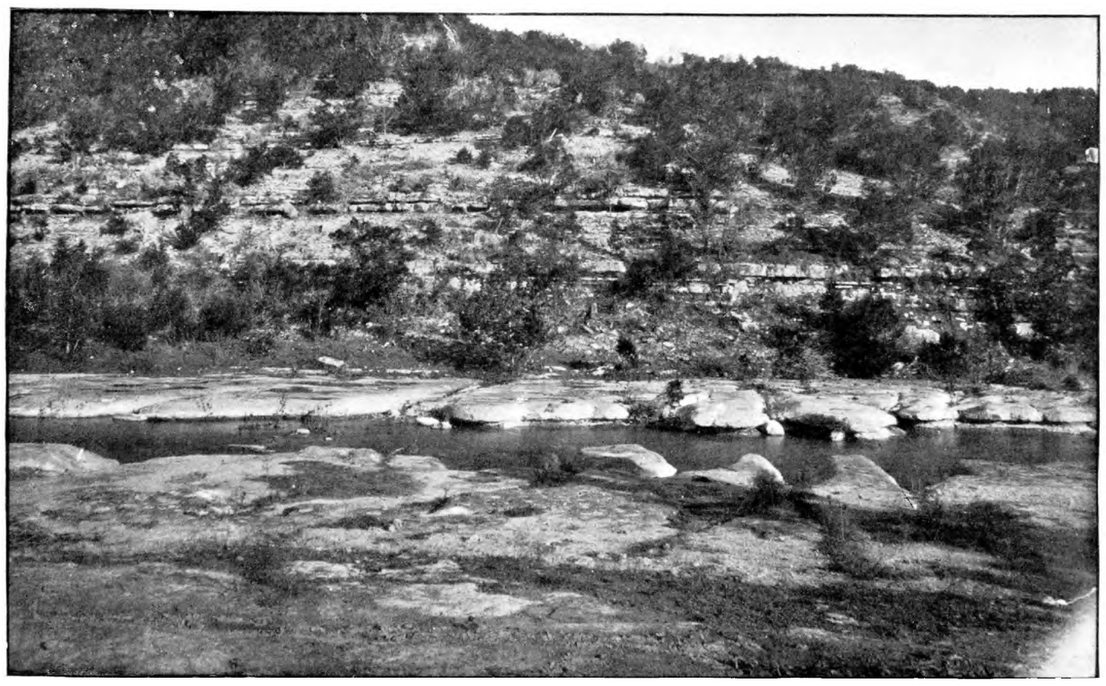

FIG. 31.—CANYON WITHIN CANYON, BULL CREEK, TRAVIS COUNTY, TEXAS.

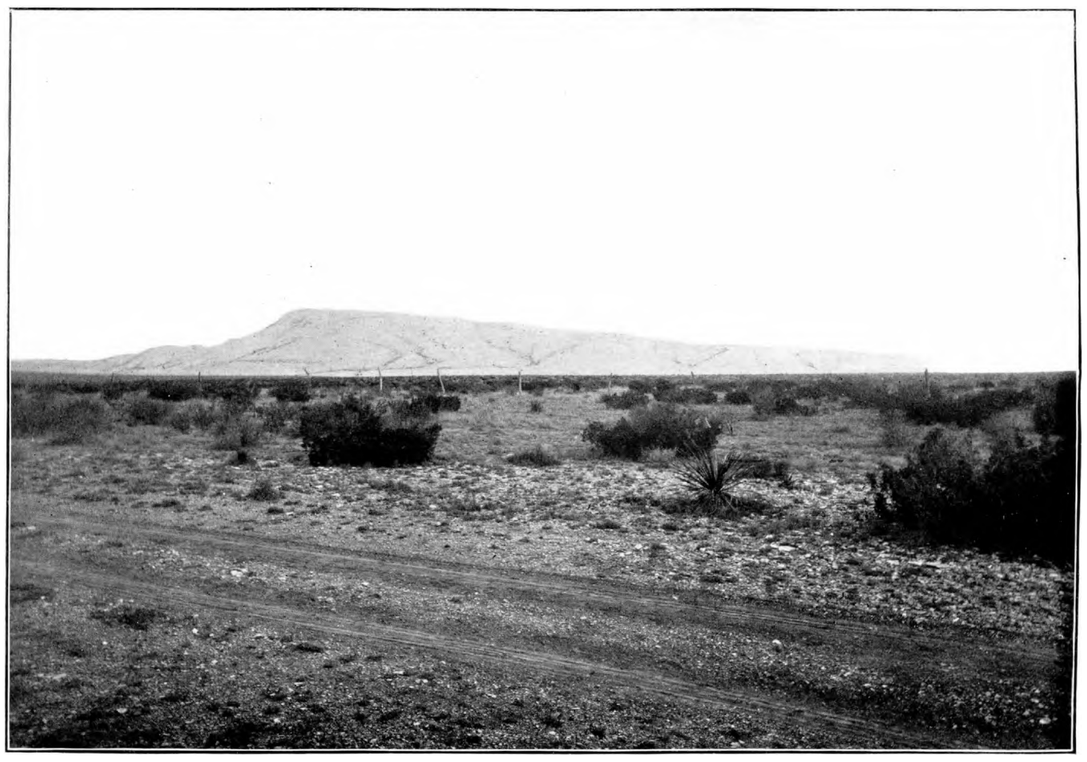

FIG. 32.—NINEPOINT CUESTA, BREWSTER COUNTY, TEXAS.

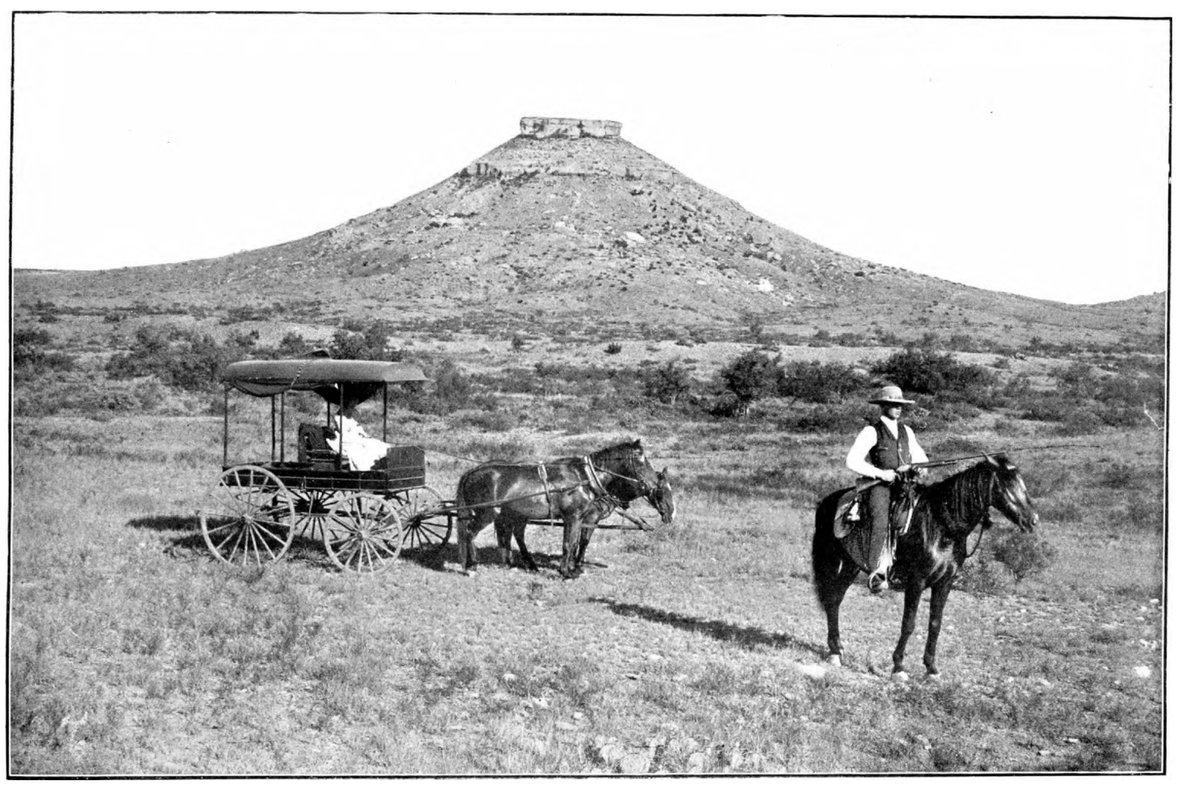

FIG. 33.—SIGNAL BUTTE, A REMNANTAL SUMMIT OF THE CALLAHAN DIVIDE, HOWARD COUNTY, TEXAS.

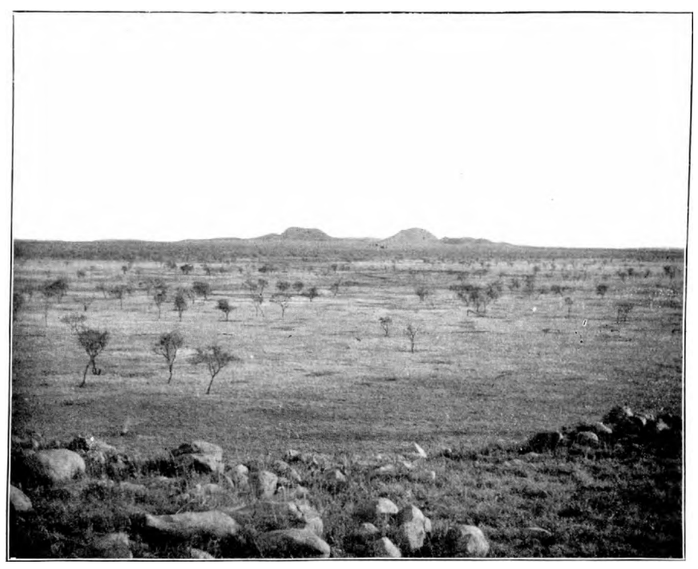

FIG. 34.—A RED BEDS PRAIRIE, CENTRAL PROVINCE; SPURS OF WICHITA MOUNTAINS IN THE BACKGROUND.

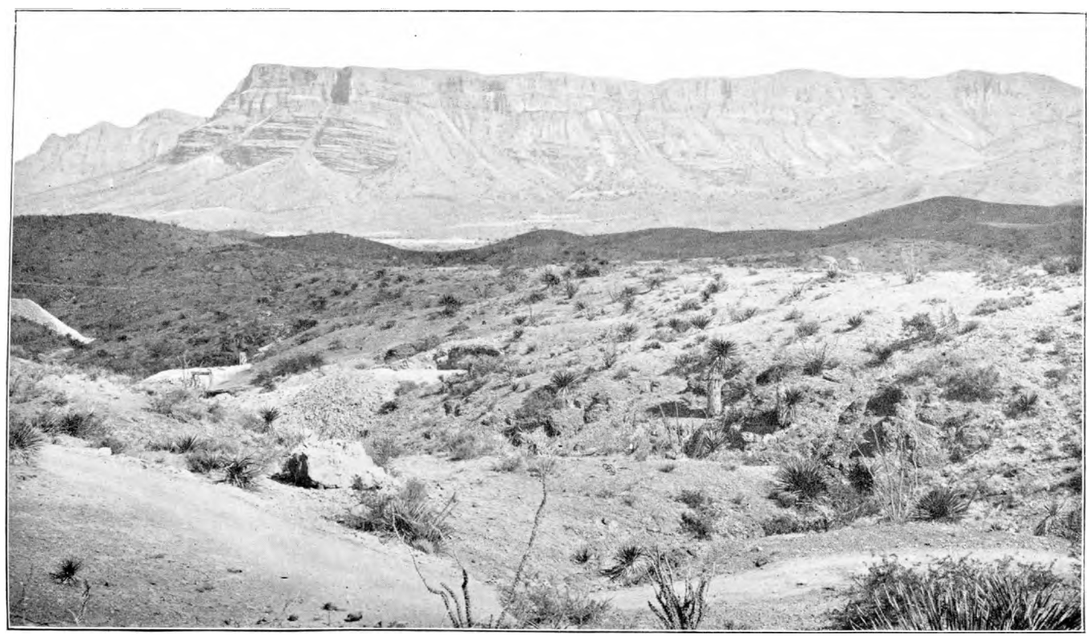

FIG. 35.—SIERRA DIABLO, A PLATEAU MOUNTAIN NORTH OF VAN HORN, TEXAS.

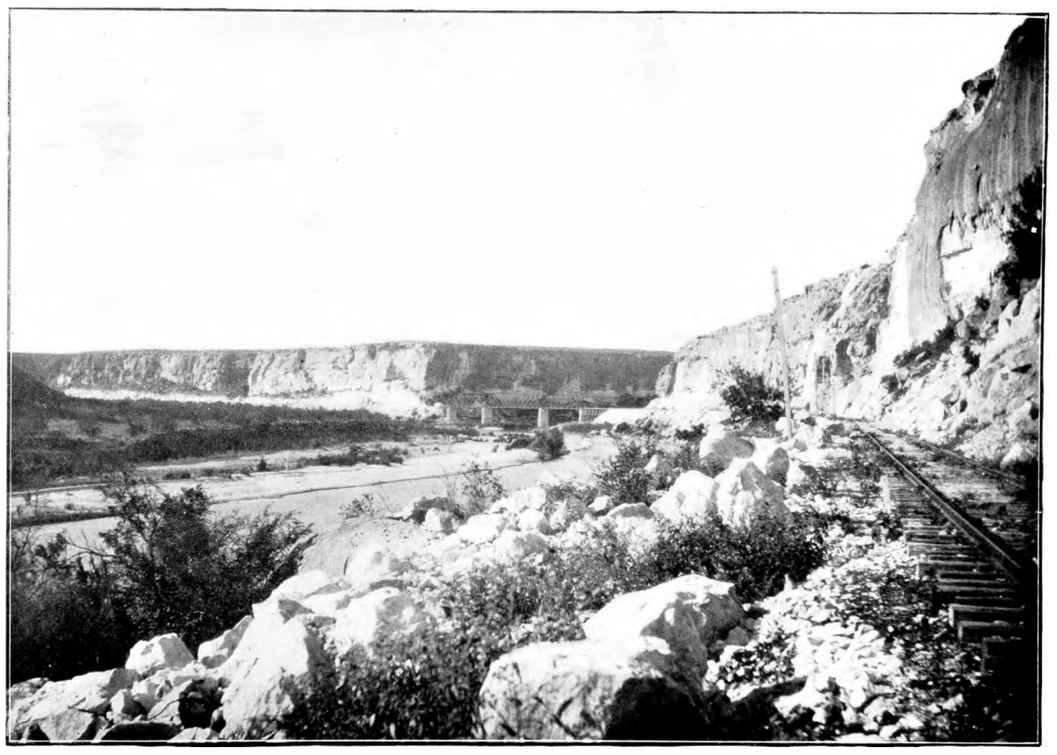

FIG. 36.—MOUTH OF PECOS RIVER, RIO GRANDE CANYON.

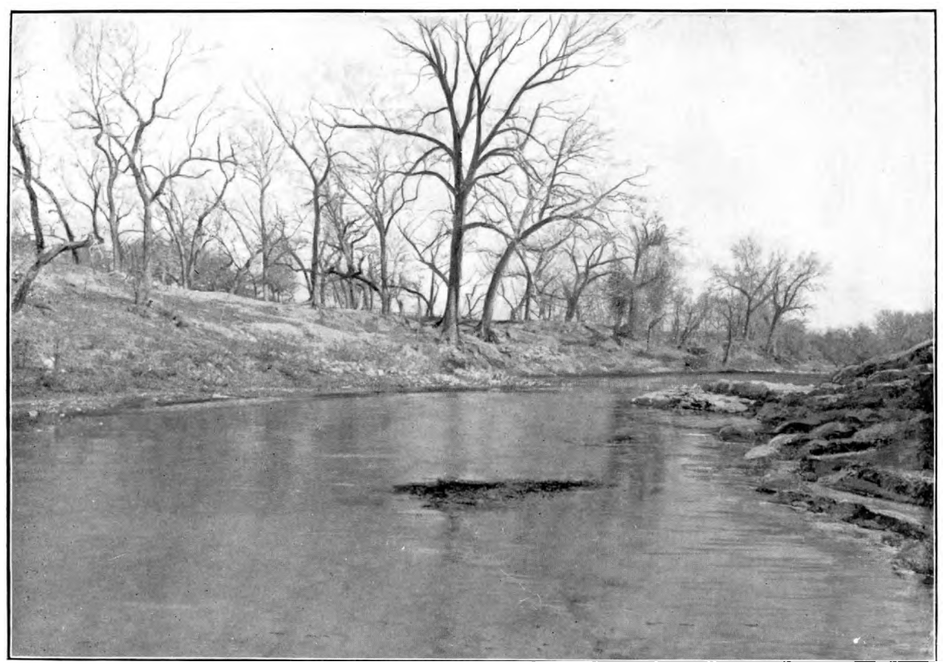

FIG. 37.—BARTON CREEK, TRAVIS COUNTY, TEXAS; A STREAM ORIGINATING FROM SPRING RISING THROUGH A ROCK FISSURE.

FIG. 38.—VALLEY OF COLORADO RIVER, LOOKING WEST FROM MOUNT BONNEL, SHOWING EROSION PLAIN ON LEFT AND ALLUVIAL TERRACE ON RIGHT.

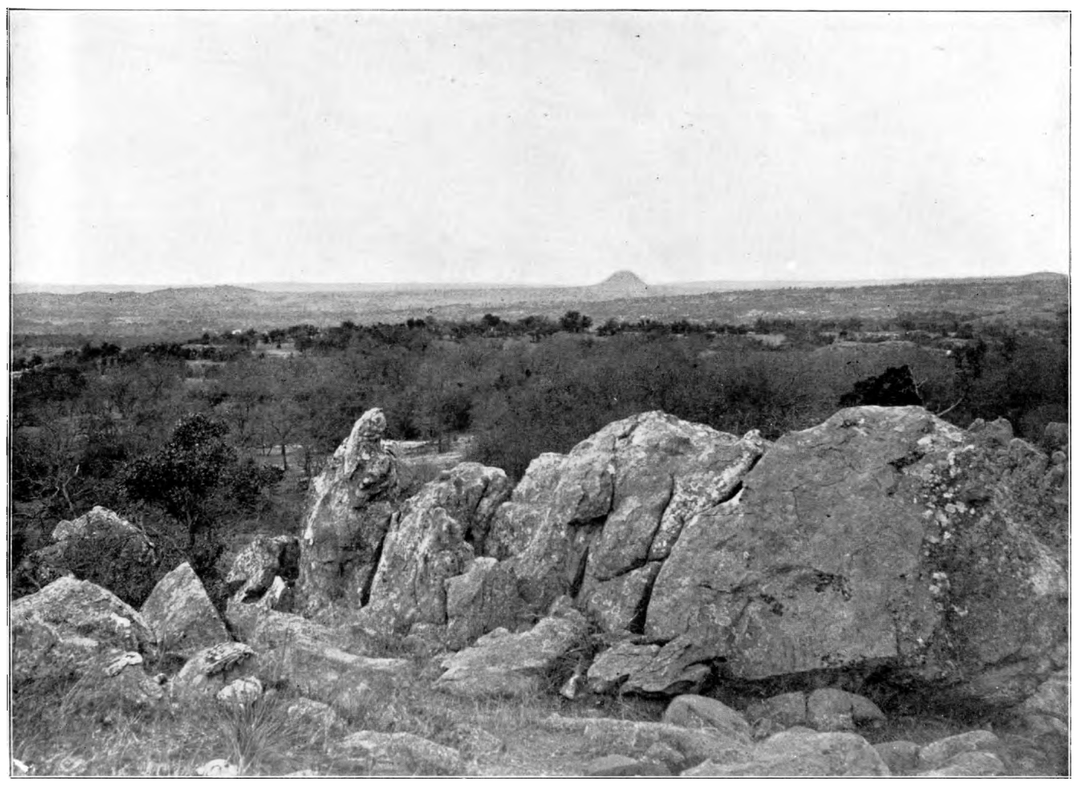

FIG. 39.—A VIEW OF THE BURNET COUNTRY.

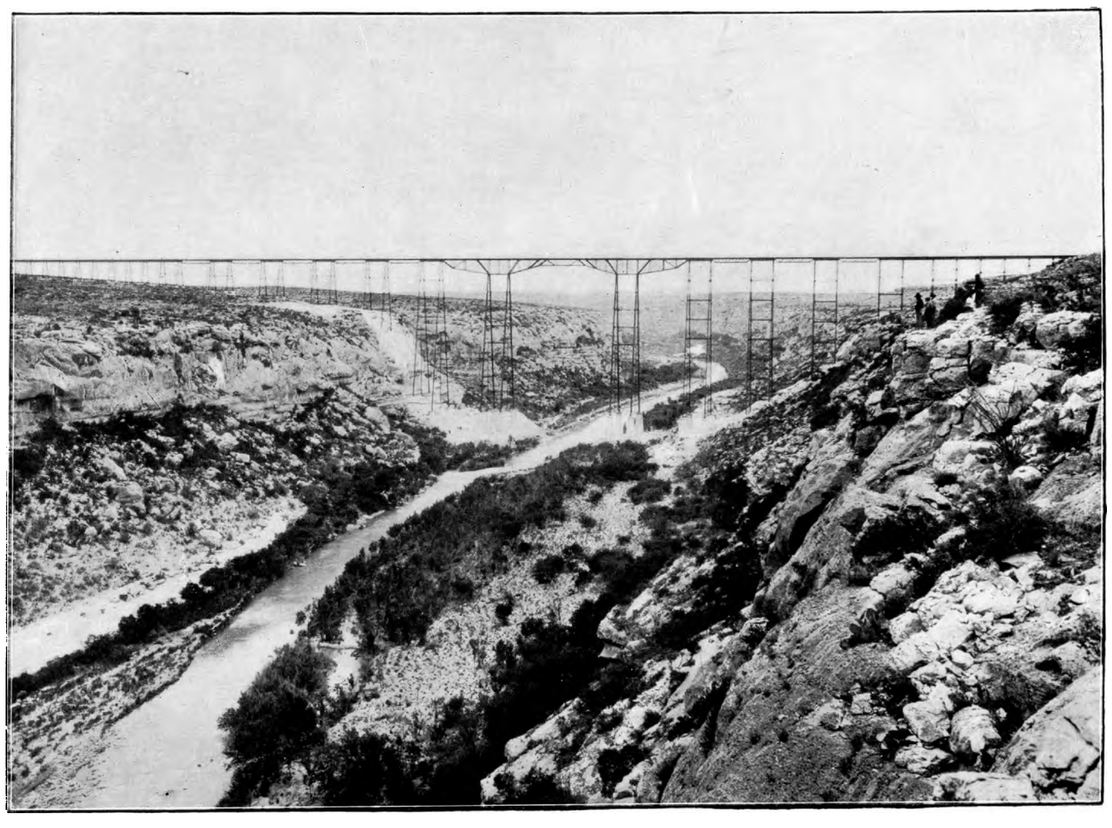

FIG. 40.—PECOS RIVER CANYON; SOUTHERN PACIFIC RAILROAD BRIDGE.

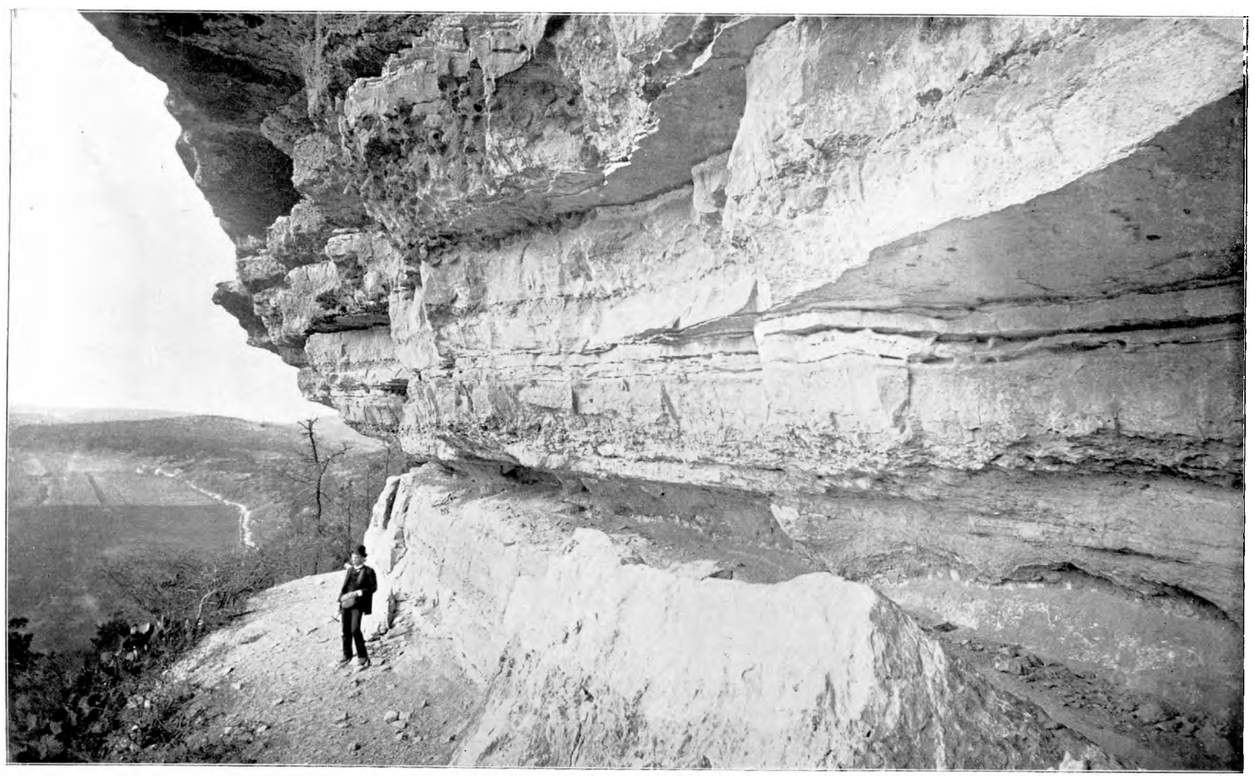

FIG. 41.—BLUFF OF COLORADO RIVER, MOUNT BONNEL, NEAR AUSTIN, TEXAS.

FIG. 42.—CANADIAN RIVER, CENTRAL PROVINCE, OKLAHOMA.

TYPES OF MOUNTAINS

U.S. GEOLOGICAL SURVEY
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FIG. 43.—SIERRA BLANCA, EL PASO COUNTY, TEXAS.

FIG. 44.—FRANKLIN MOUNTAINS AND HUECO BOLSON, EL PASO COUNTY, TEXAS.

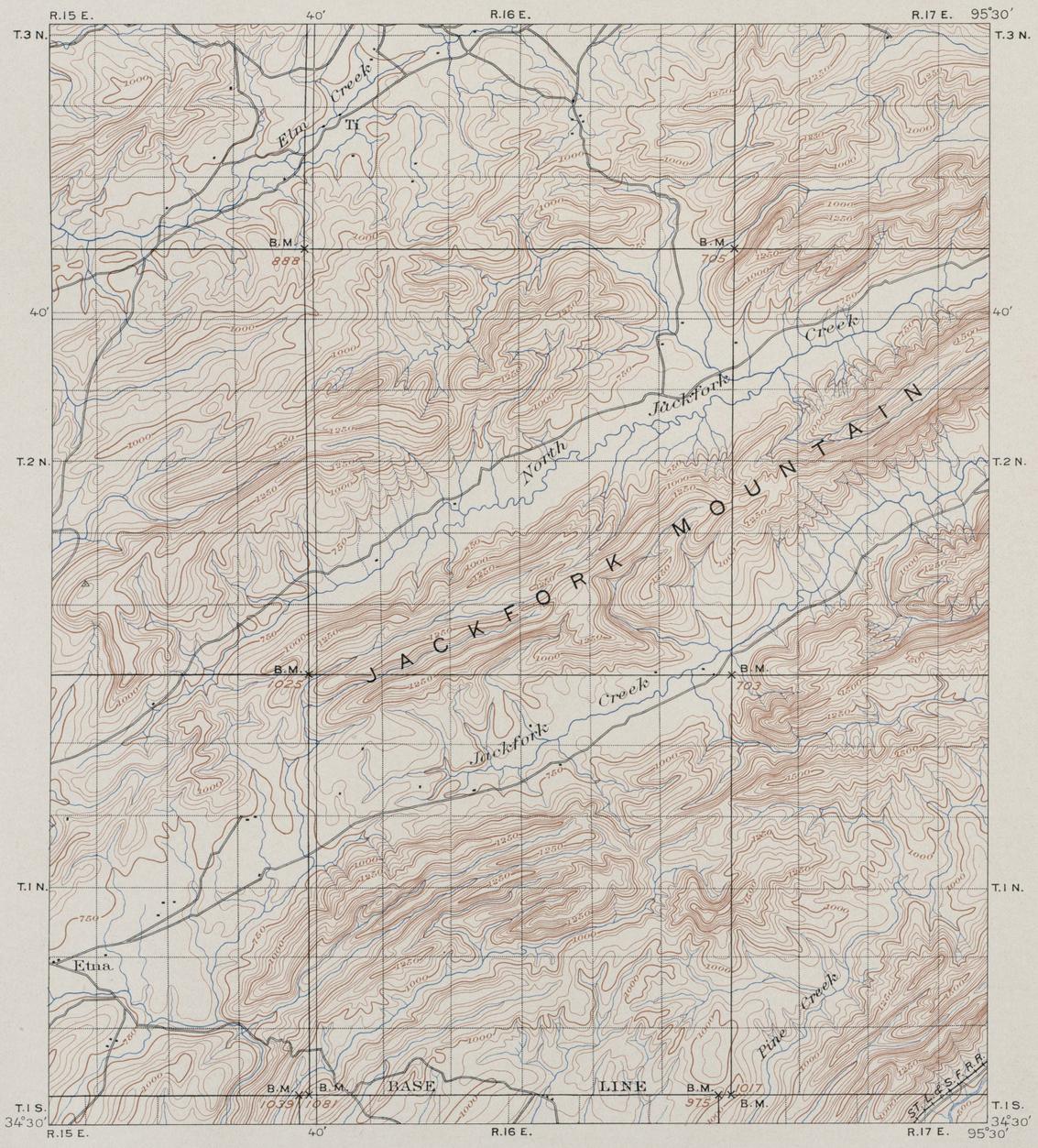

FIG. 45.—OUACHITA MOUNTAINS, CHOCTAW NATION, INDIAN TERRITORY.

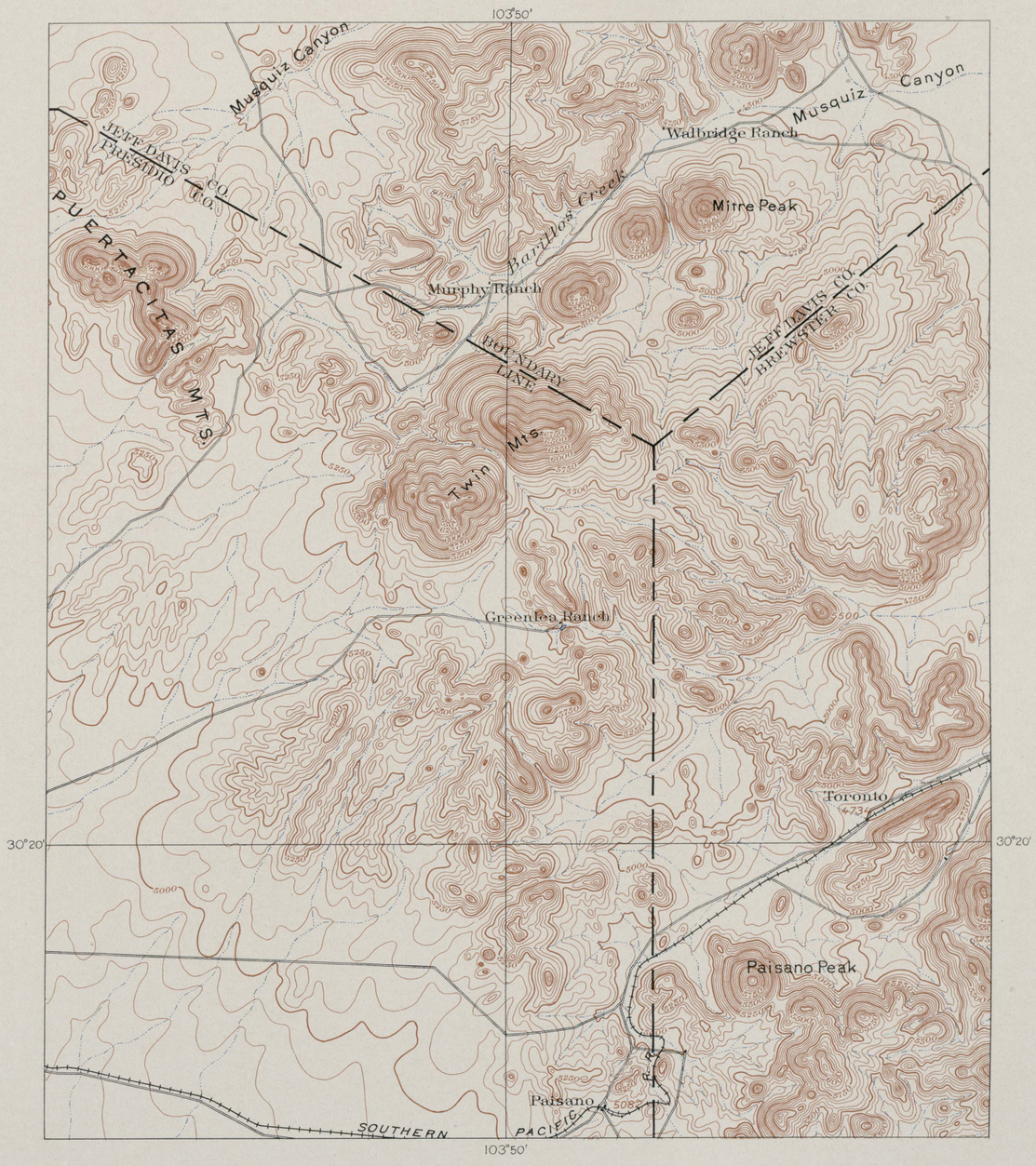

FIG. 46.—DAVIS MOUNTAINS, TEXAS.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

Edition of April 1900.

SHEET VII

U.S.GEOLOGICAL SURVEY
CHARLES D.WALCOTT, DIRECTOR

TYPES OF PLAINS AND SCARPS

TOPOGRAPHIC ATLAS, FOLIO 3

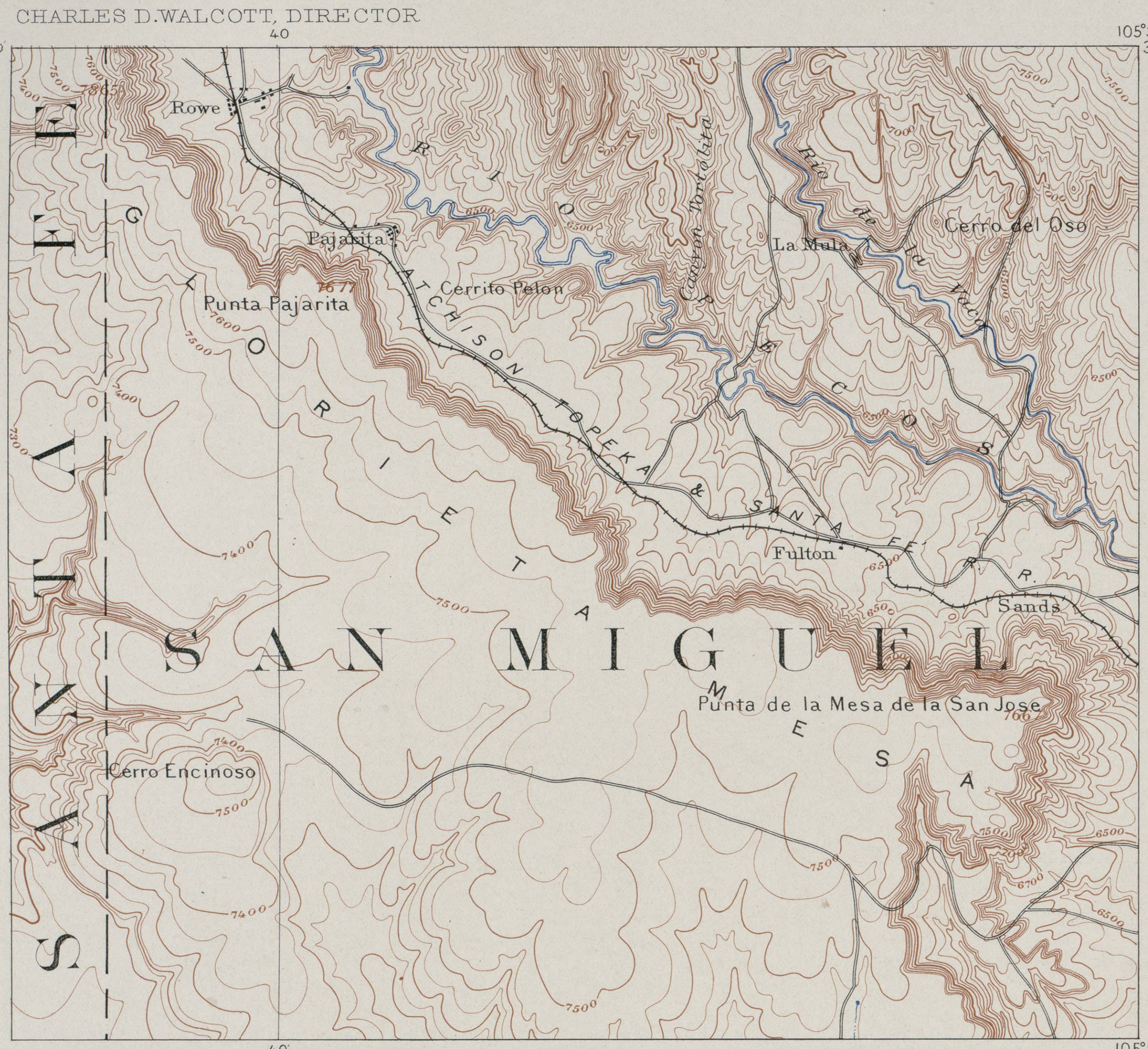

FIG. 47.—PARTING VALLEY BETWEEN THE ROCKY MOUNTAINS AND MESA PLAINS, SOUTH OF SANTA FE, NEW MEXICO.
CONTOUR INTERVAL 50 FEET.

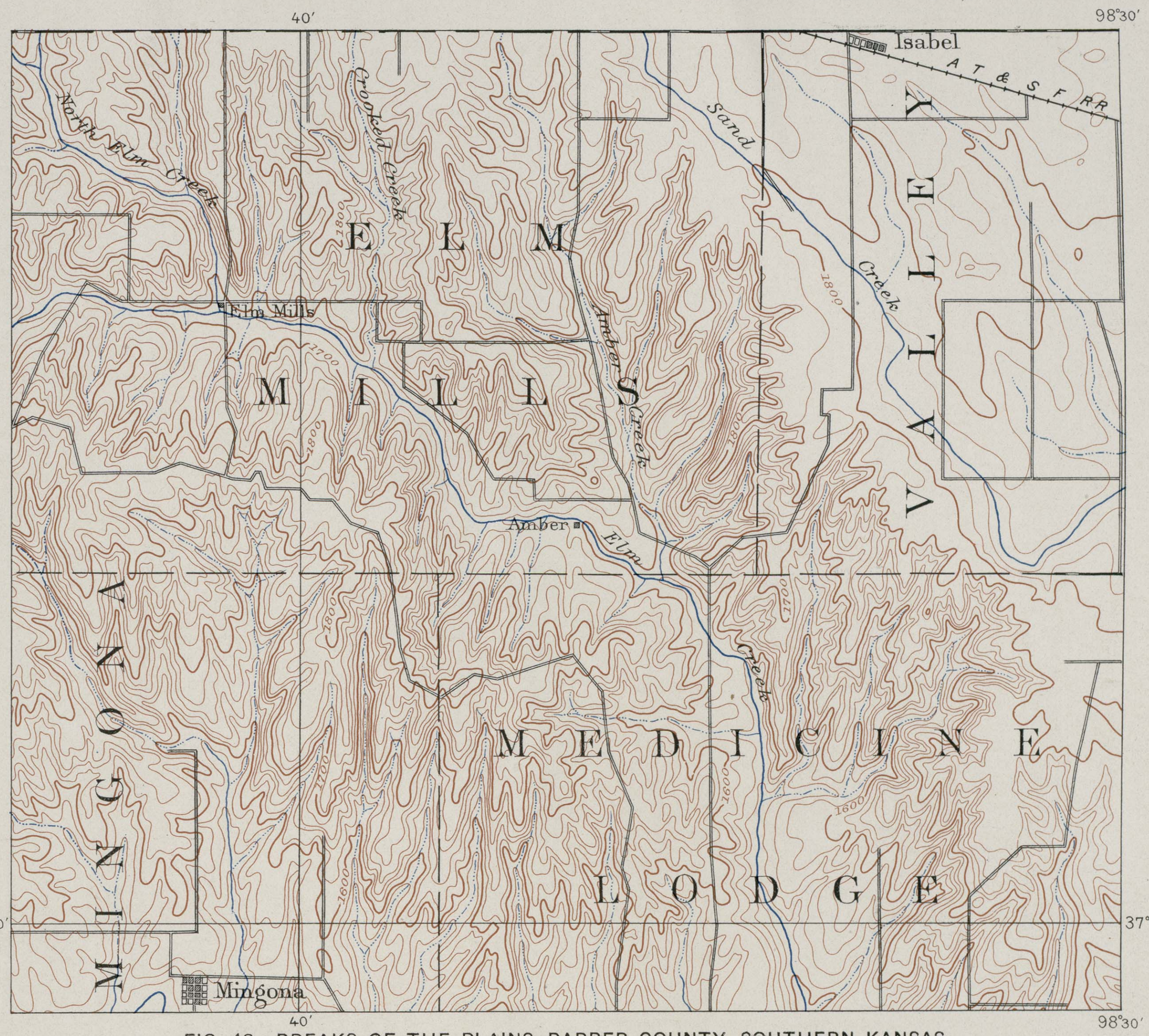

FIG. 48.—BREAKS OF THE PLAINS, BARBER COUNTY, SOUTHERN KANSAS.
CONTOUR INTERVAL 20 FEET.

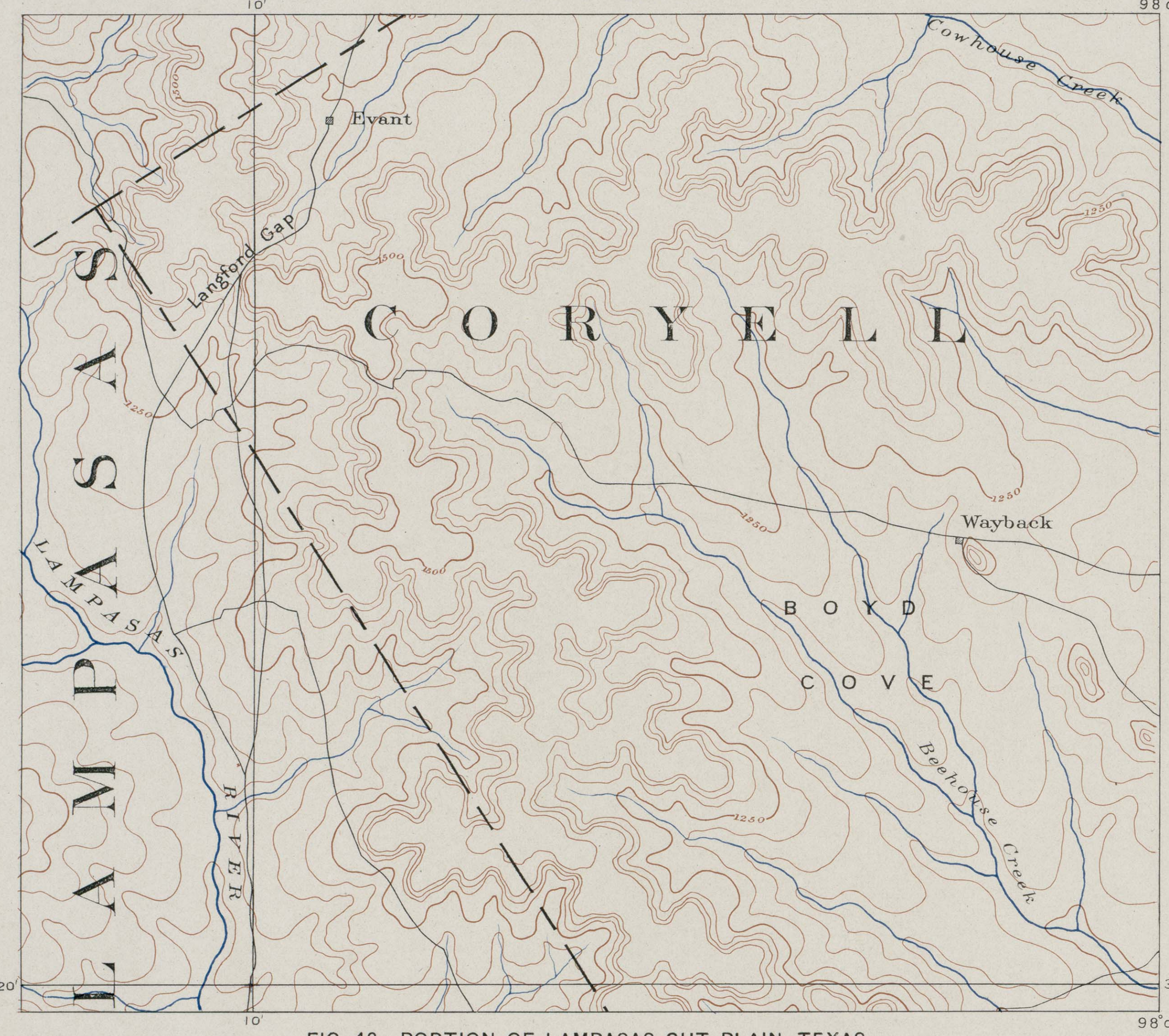

FIG. 49.—PORTION OF LAMPASAS CUT PLAIN, TEXAS.
CONTOUR INTERVAL 50 FEET.

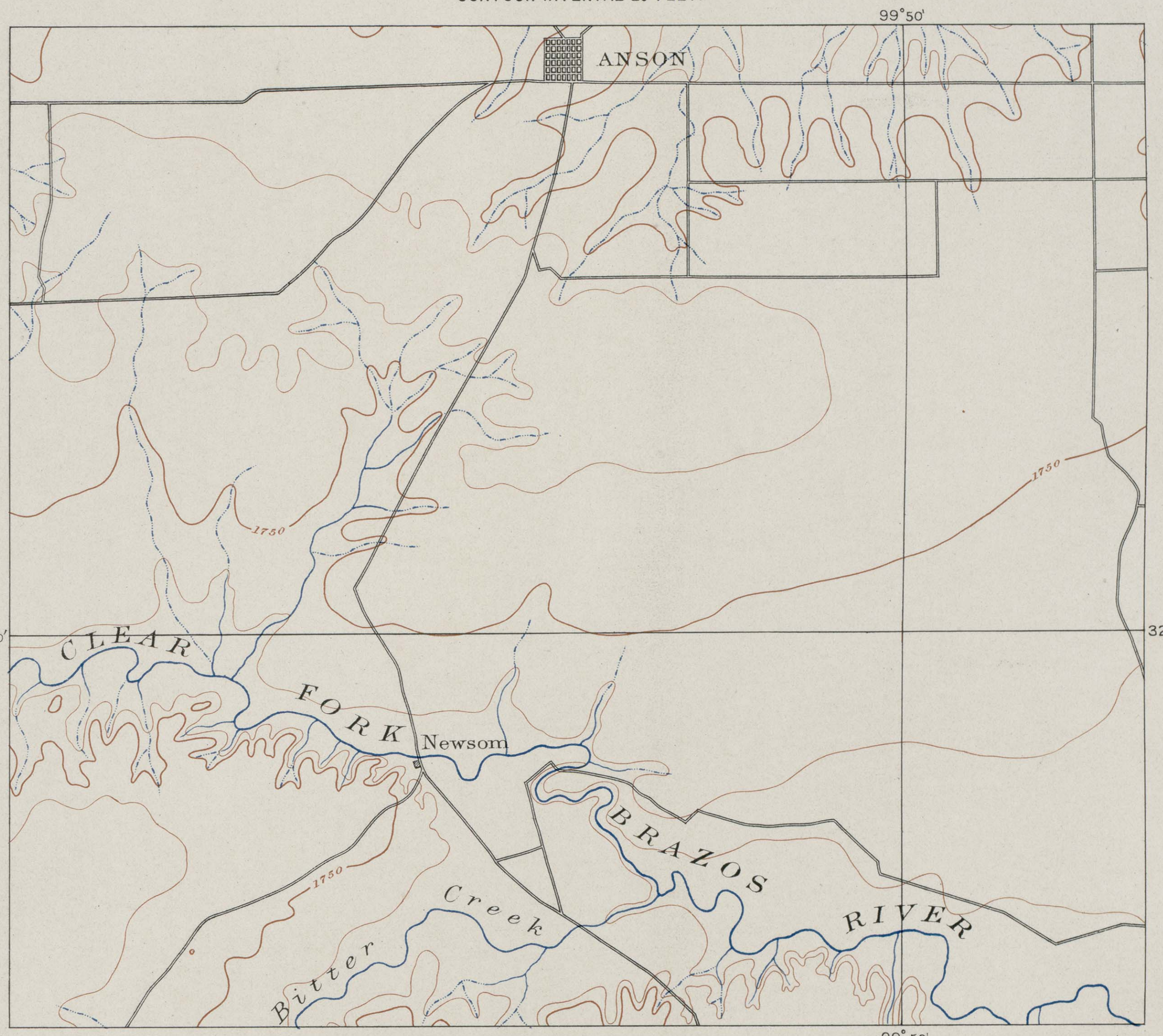

FIG. 50.—RED BEDS PRAIRIE AND STRATUM SCARPS OF THE CENTRAL PROVINCE, JONES COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

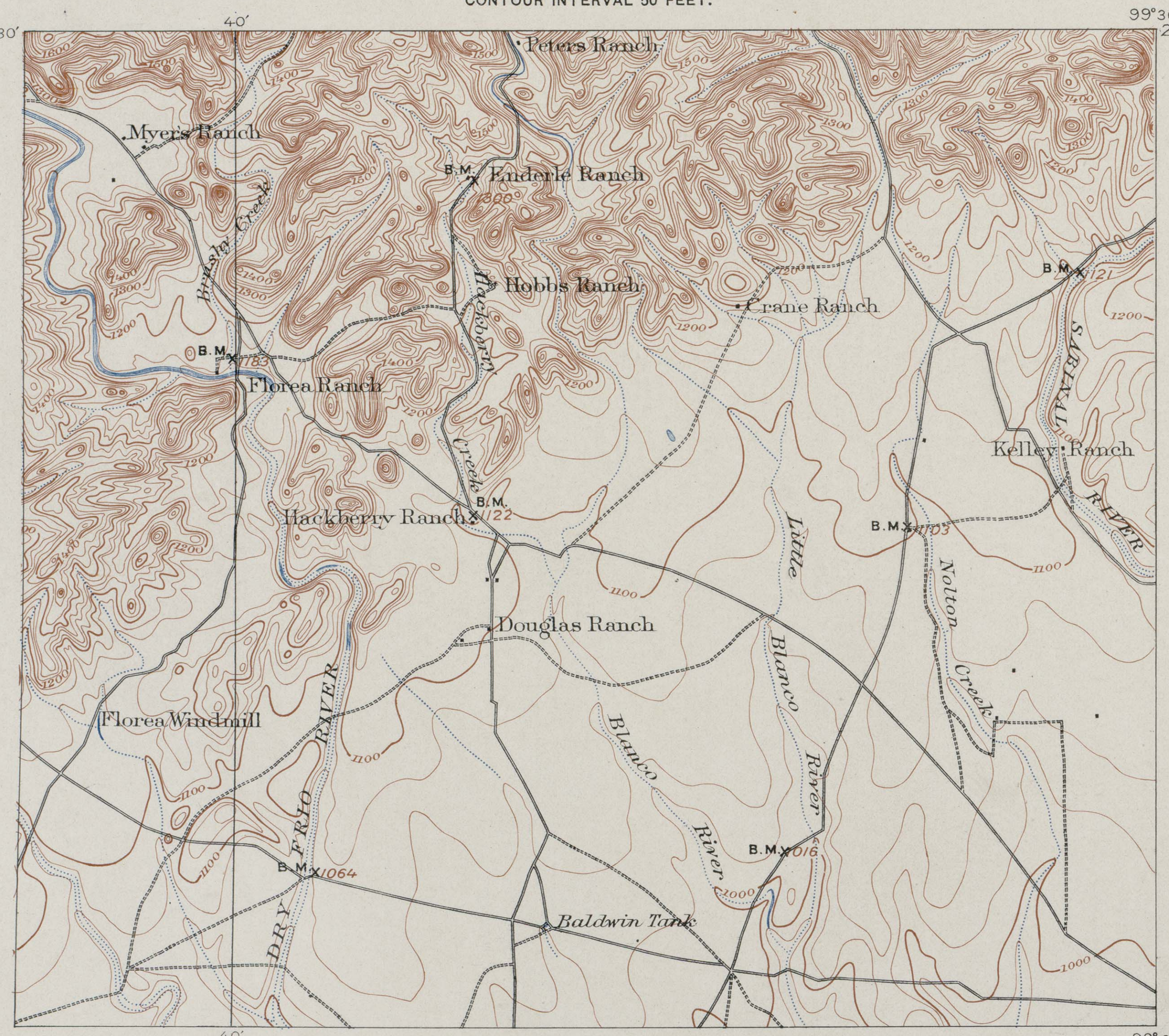

FIG. 51.—BALCONES FAULT SCARP, UVALDE COUNTY, TEXAS.
CONTOUR INTERVAL 25 FEET.

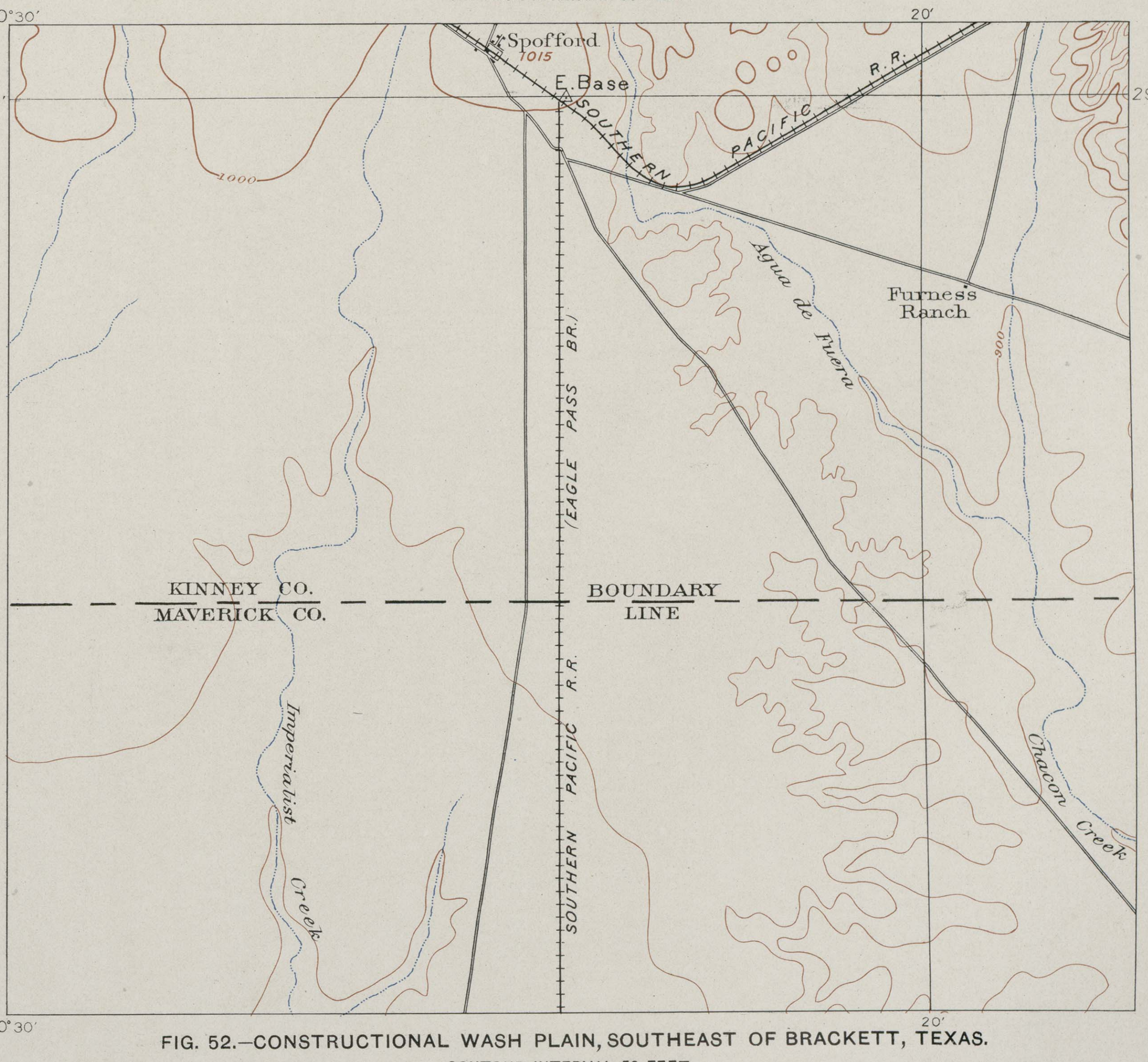

FIG. 52.—CONSTRUCTIONAL WASH PLAIN, SOUTHEAST OF BRACKETT, TEXAS.
CONTOUR INTERVAL 50 FEET.

Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Datum is mean sea level.

Edition of April 1900.

SHEET VIII

TYPES OF PLAINS AND SCARPS

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TOPOGRAPHIC ATLAS, FOLIO 3

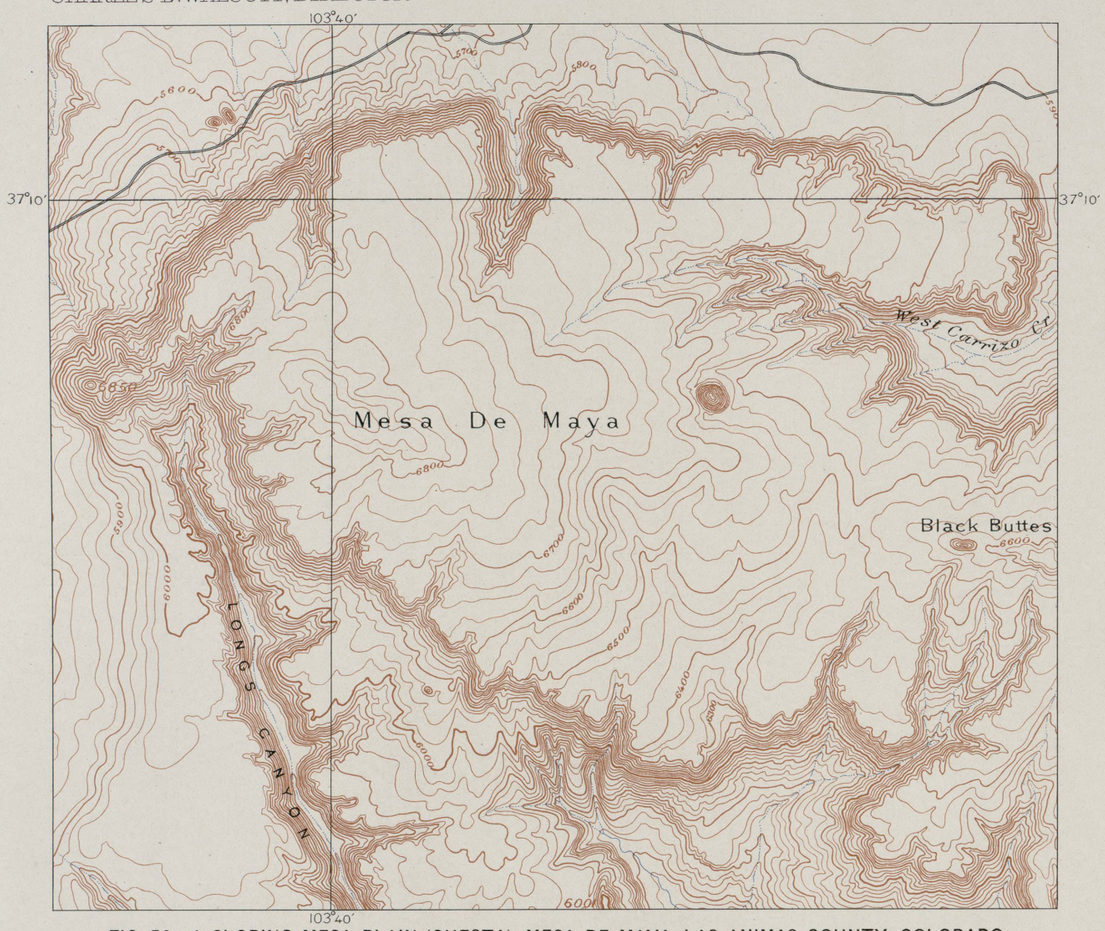

FIG. 53.—A SLOPING MESA PLAIN (CUESTA), MESA DE MAYA, LAS ANIMAS COUNTY, COLORADO.
CONTOUR INTERVAL 25 FEET.

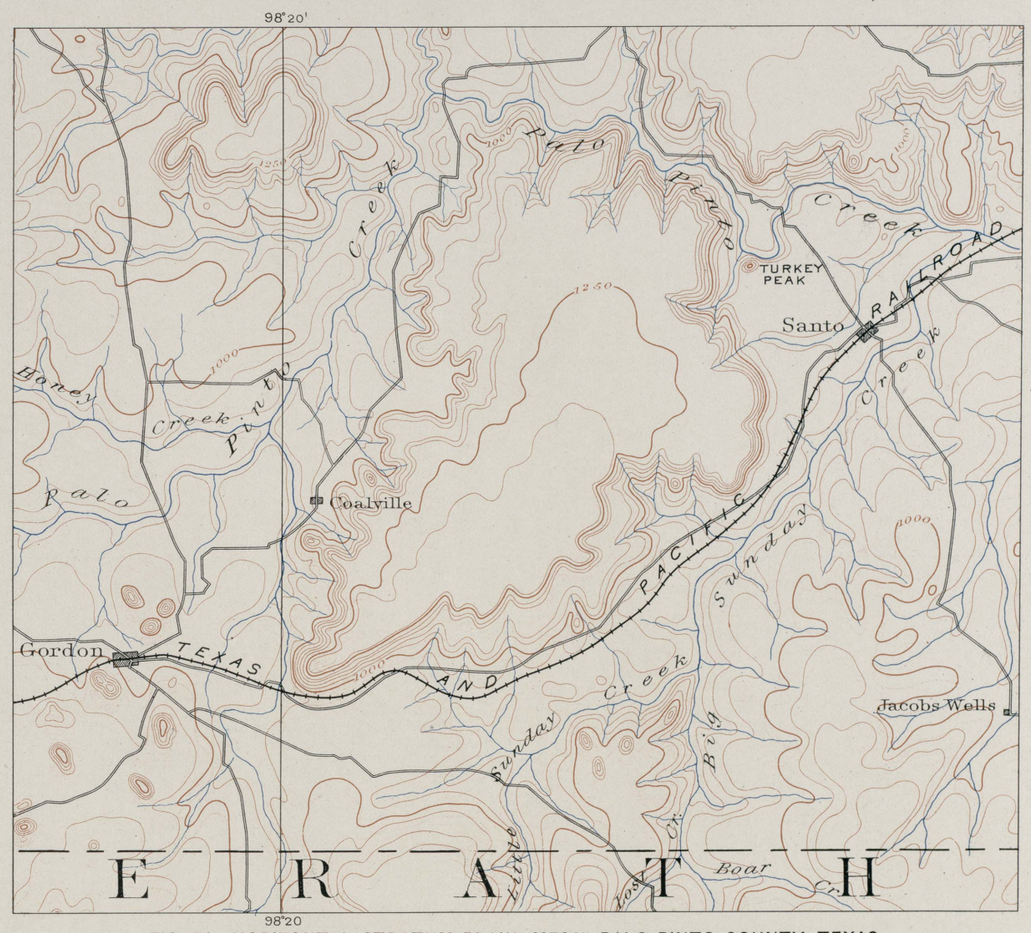

FIG. 54.—HORIZONTAL STRATUM PLAIN (MESA), PALO PINTO COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

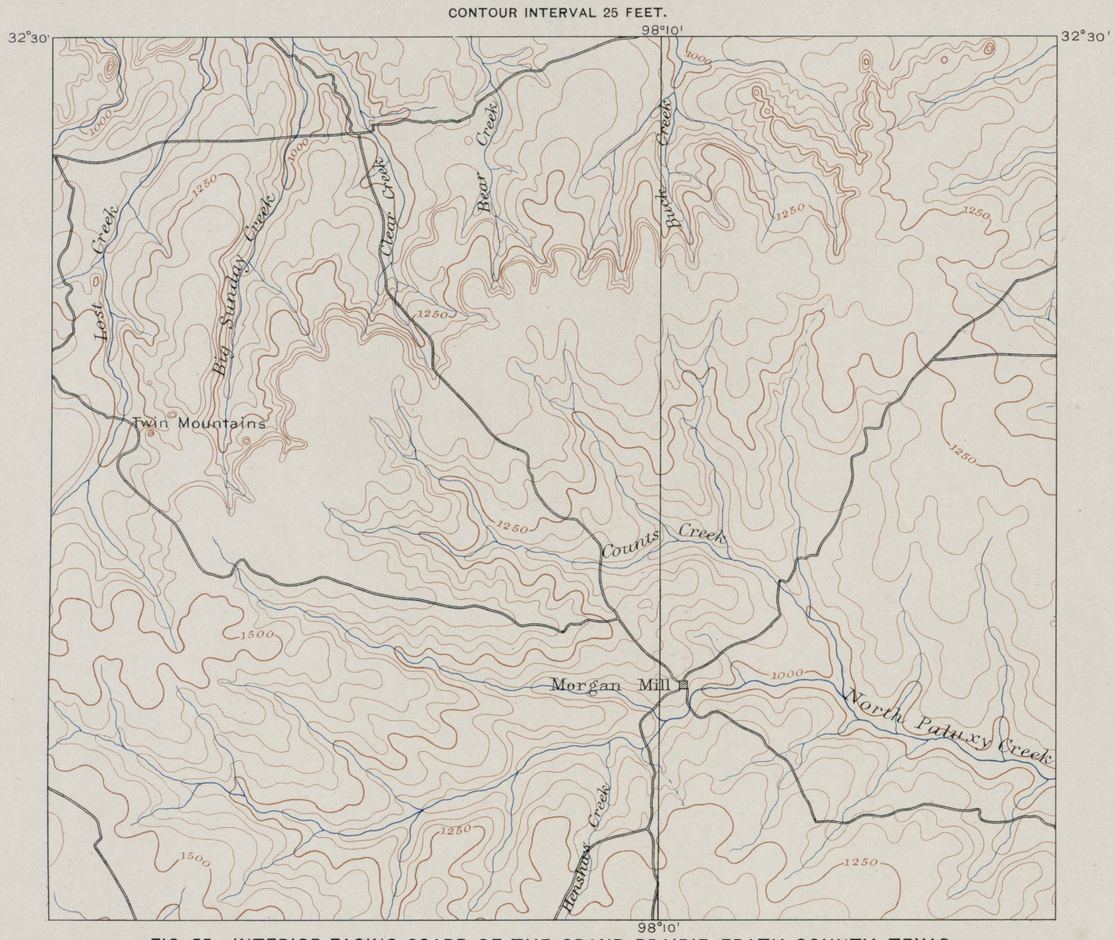

FIG. 55.—INTERIOR-FACING SCARP OF THE GRAND PRAIRIE, ERATH COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

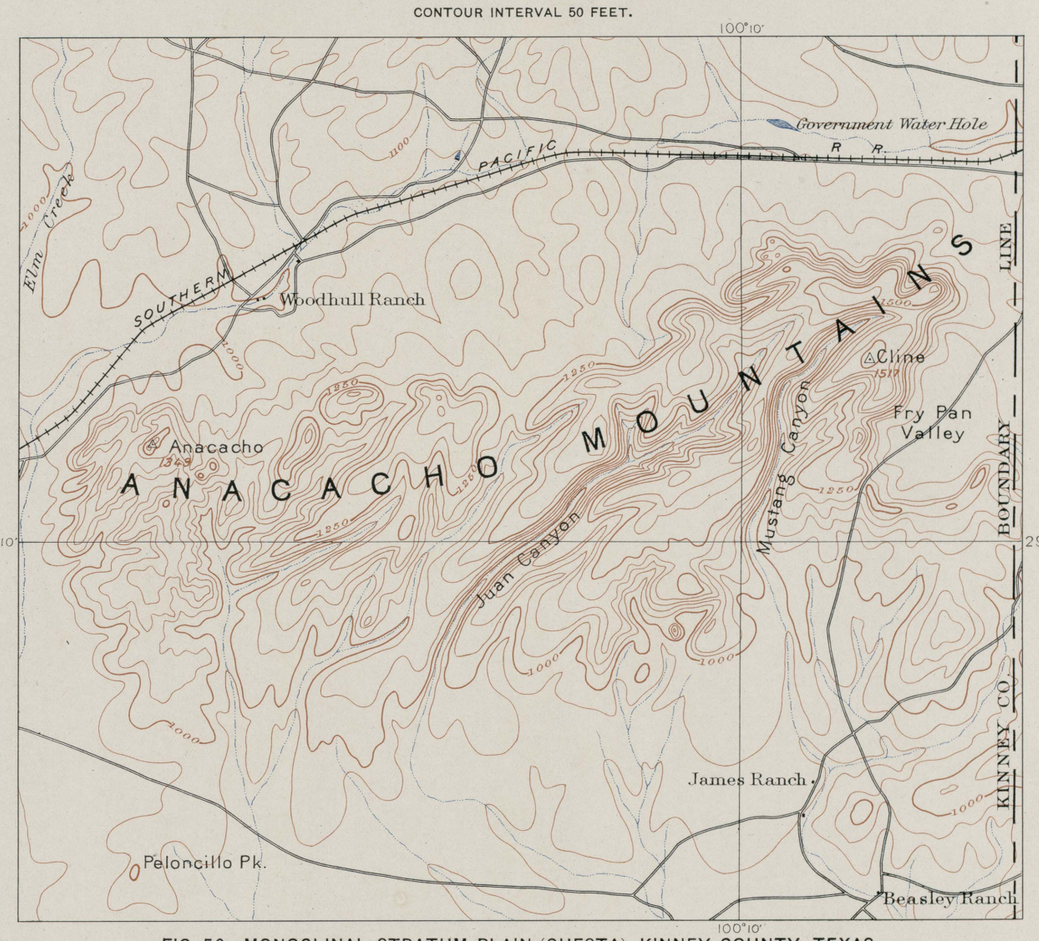

FIG. 56.—MONOCLINAL STRATUM PLAIN (CUESTA), KINNEY COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

FIG. 57.—DISSECTED STRATUM PLAIN, SOUTH EDGE OF EDWARDS PLATEAU, EDWARDS COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

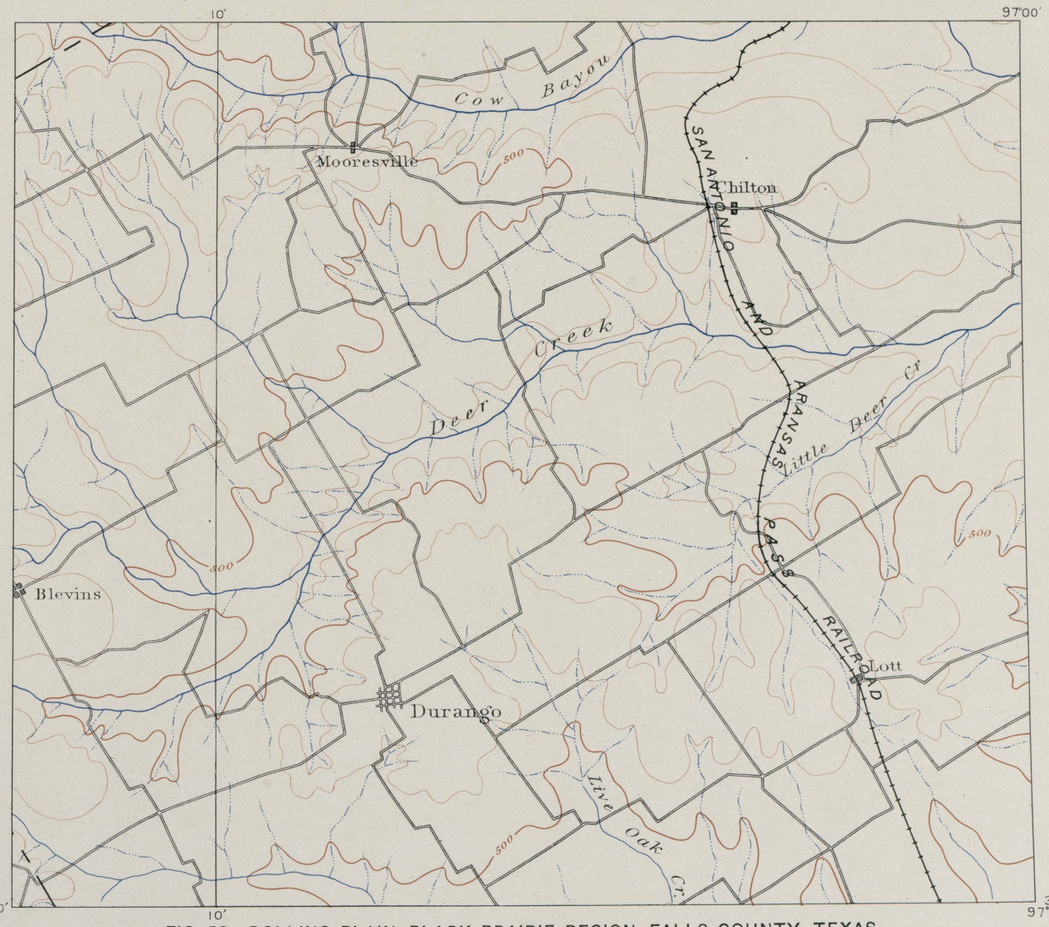

FIG. 58.—ROLLING PLAIN, BLACK PRAIRIE REGION, FALLS COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

Scale 1/125000

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Datum is mean sea level.

Edition of April 1900.

TYPES OF PLAINS AND SCARPS

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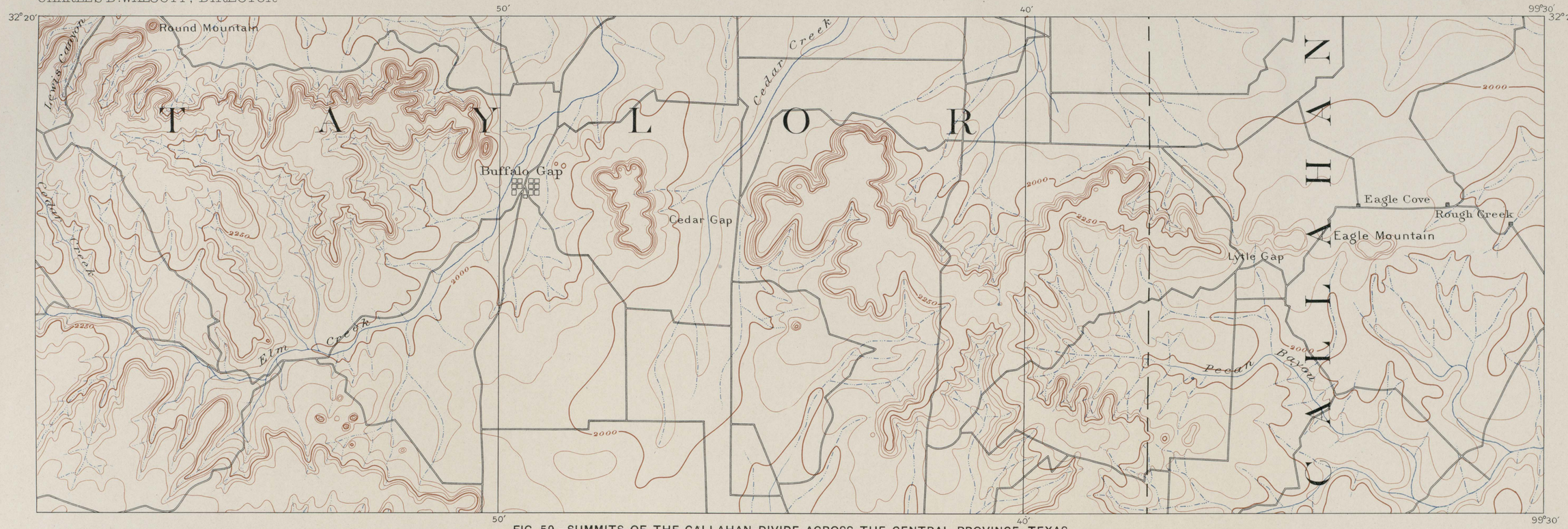

FIG. 59.—SUMMITS OF THE CALLAHAN DIVIDE ACROSS THE CENTRAL PROVINCE, TEXAS.

FIG. 60.—CUESTA DEL BURRO, SHOWING RELATIONS OF BOLSON PLAINS, CUESTAS, AND TRANS-PECOS MOUNTAIN RANGES, PRESIDIO COUNTY, TEXAS.

Scale $\frac{1}{125000}$

1 ½ 0 1 2 3 4 5 Miles

1 ½ 0 1 2 3 4 5 Kilometers

Contour interval 50 feet.

Datum is mean sea level.

Edition of April 1900.

SHEET X

TYPES OF RIVERS AND CANYONS

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FIG. 61.—INCISED CANYON DRAINAGE, SAN MIGUEL COUNTY, NEW MEXICO.
CONTOUR INTERVAL 50 FEET.

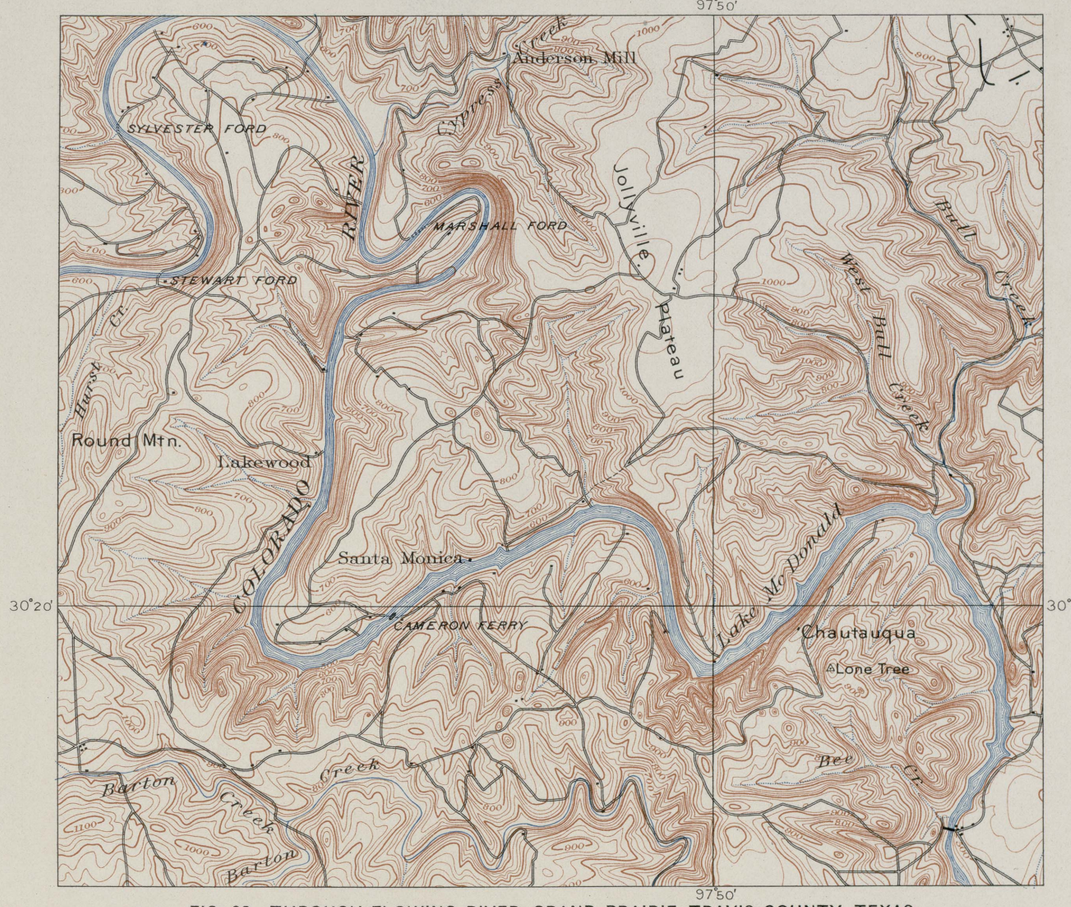

FIG. 62.—THROUGH-FLOWING RIVER, GRAND PRAIRIE, TRAVIS COUNTY, TEXAS.
CONTOUR INTERVAL 25 FEET.

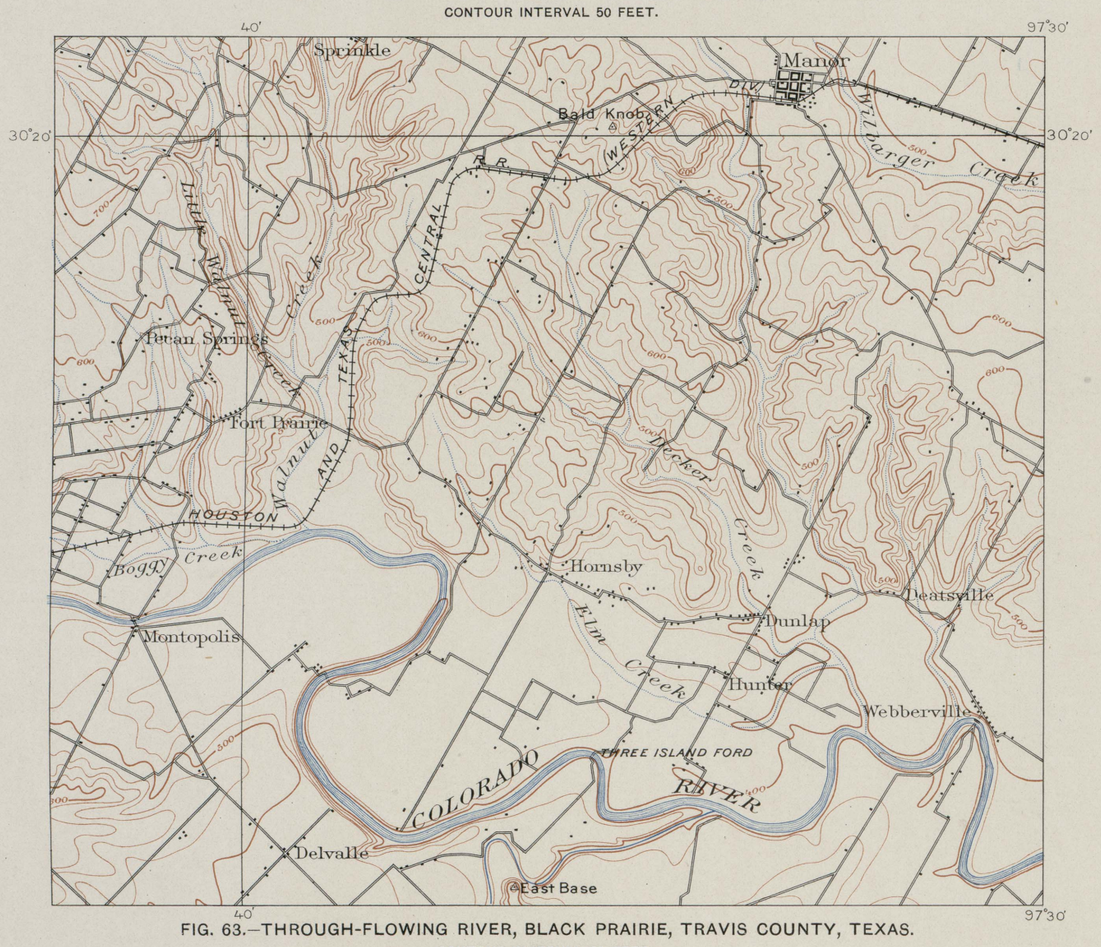

FIG. 63.—THROUGH-FLOWING RIVER, BLACK PRAIRIE, TRAVIS COUNTY, TEXAS.
CONTOUR INTERVAL 25 FEET.

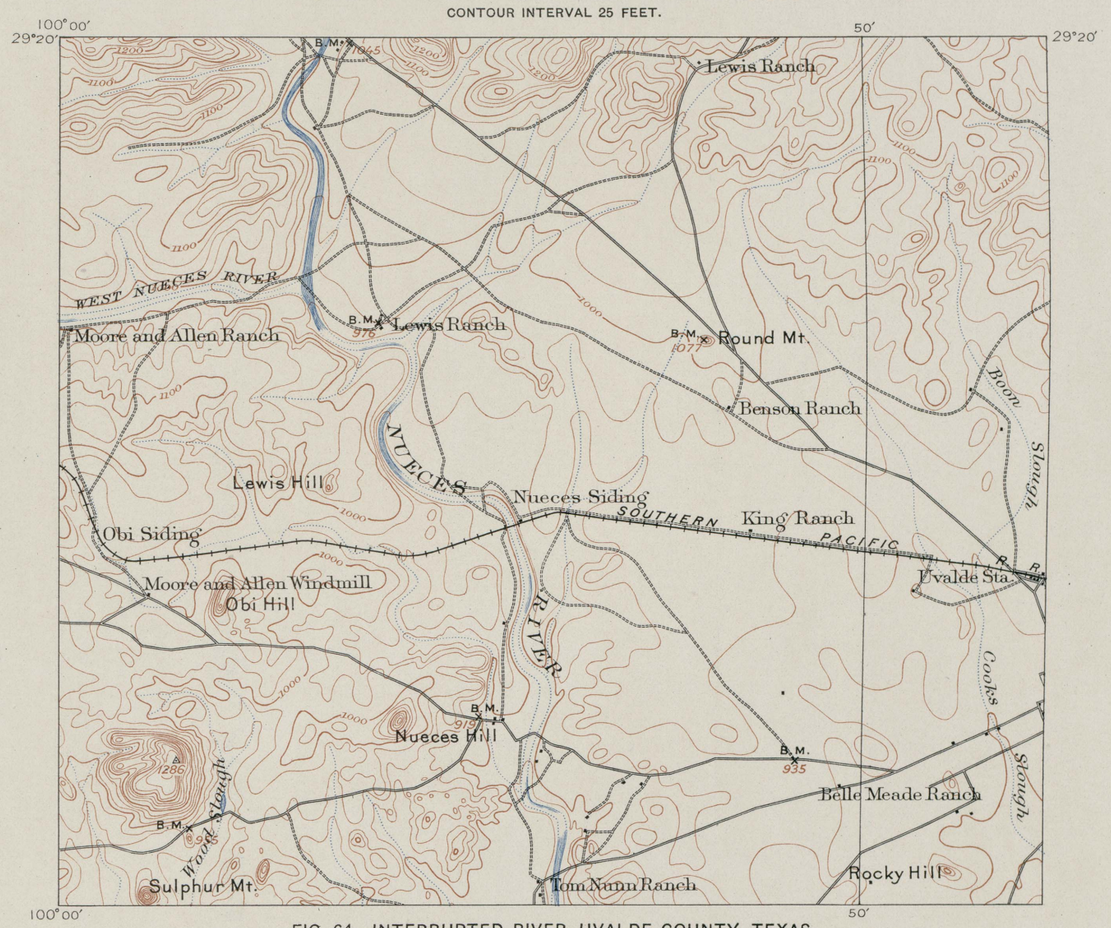

FIG. 64.—INTERRUPTED RIVER, UVALDE COUNTY, TEXAS.
CONTOUR INTERVAL 25 FEET.

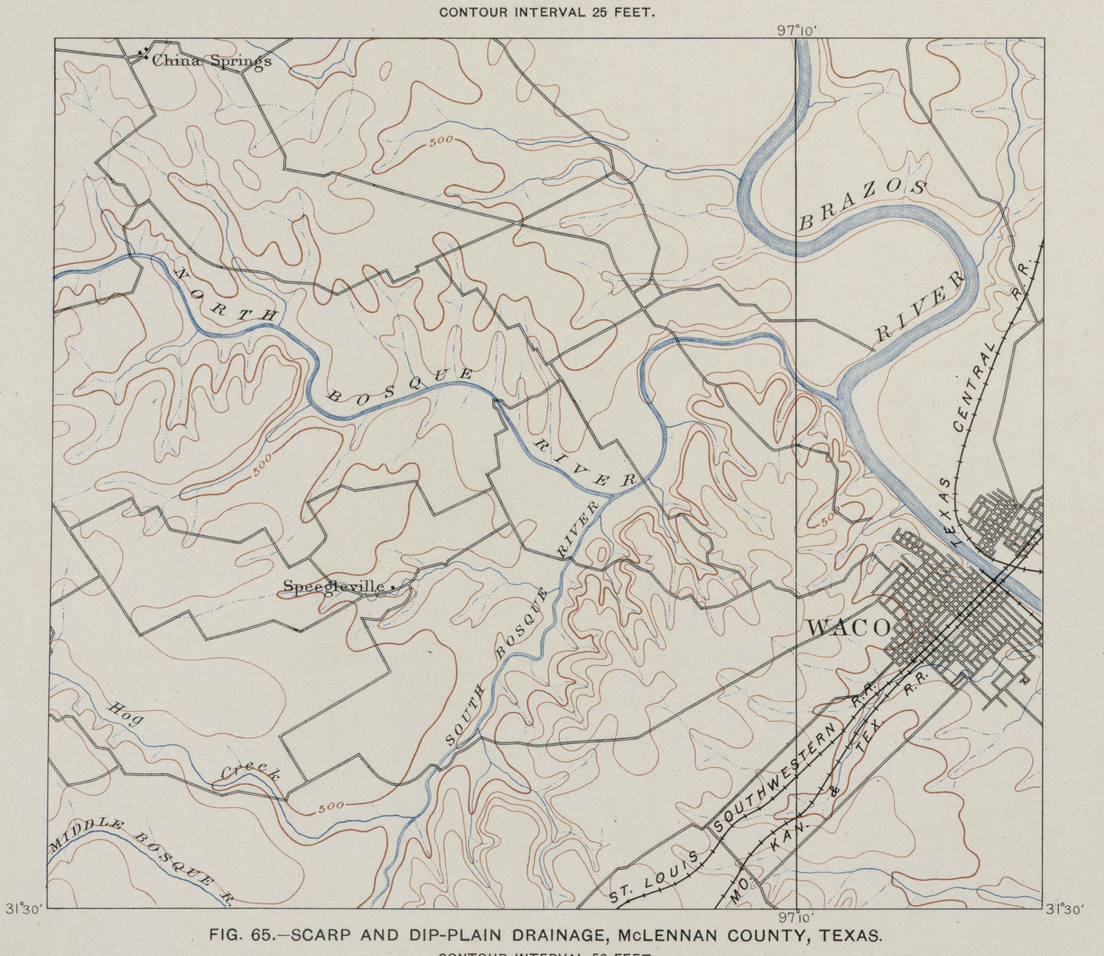

FIG. 65.—SCARP AND DIP-PLAIN DRAINAGE, McLENNAN COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

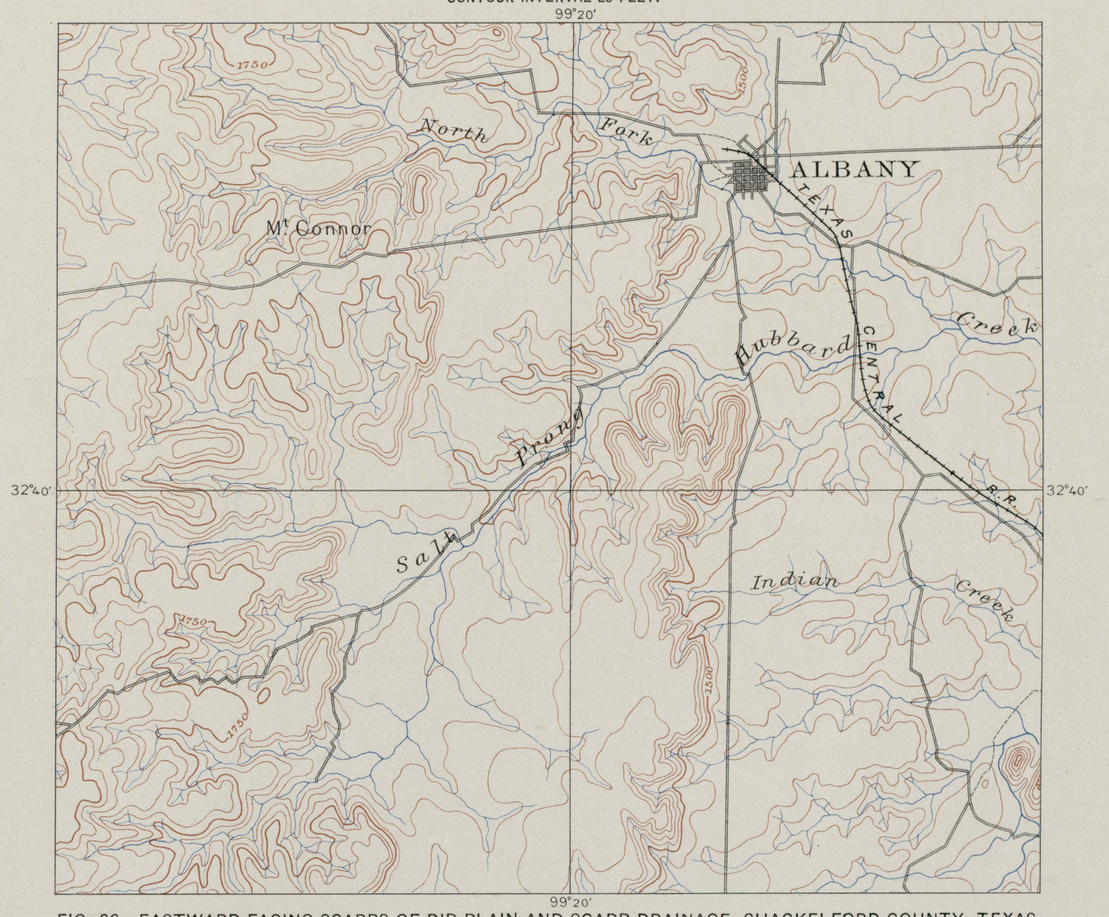

FIG. 66.—EASTWARD-FACING SCARPS OF DIP-PLAIN AND SCARP DRAINAGE, SHACKELFORD COUNTY, TEXAS.
CONTOUR INTERVAL 50 FEET.

Scale 1/125000
1 1/2 0 1 2 3 4 5 Miles
1 1/2 0 1 2 3 4 5 Kilometers

Datum is mean sea level.

Edition of April 1900.

MAP OF TEXAS AND PARTS OF ADJOINING TERRITORIES

Compiled by and under the direction of

ROBERT T. HILL

Drawn by

Henry S. Selden and Willard D. Johnson

Scale 25 miles=1 inch

75 20 15 10 5 0 25 50 75 100 Miles

25 20 15 10 5 0 25 50 75 100 Kilometers

Contour interval 250 feet

1899

Edition of May 1904.

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